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CATEGORICAL ONTOLOGY OF COMPLEX SYSTEMS, META–SYSTEMS AND LEVELS: THE EMERGENCE OF LIFE, HUMAN CONSCIOUSNESS AND SOCIETY.

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Abstract. The task of developing novel and improved methodological tools for a categorical ontology of complex spacetime structures and the ontological theory of levels is here considered from several perspectives including both the quantum-molecular and complex-relational ones. Our novel conceptual framework is aimed at helping both philosophers and natural scientists to understand and organize the spacetime ontology of highly complex systems in terms of a categorical formalism of Poli's ontological theory of levels. Such highly complex systems, and indeed their emergent *meta-systems* dynamics are relevant to a wide variety of biosystems or organisms. They are suggested to be also necessary for understanding the human brain, the mind and society levels. It may be that we are now at a stage of the development in philosophy and science that such tools are beginning to emerge, or are indeed in the process of becoming available from several exact sciences, such as: logics, mathematics, physics, molecular and theoretical genetics, molecular biology, relational biology, and so on, as a result of trends towards unity in logics, mathematics and physics. An outline of a Categorical Ontology of Space and Time, or Spacetime, is presented for emergent biosystems, super-complex dynamics, biological evolution and human consciousness. Relational structures of organisms and the human mind are naturally represented in terms of novel variable topology concepts, non-Abelian categories and Higher Dimensional Algebra, relatively new concepts that would be also described in the following sections. A unifying theme of local-to-global approaches to organismic development, evolution and human consciousness leads to novel patterns of relations that emerge in super- and ultra- complex systems in terms of compositions of local procedures; the latter can be defined, for example, in terms of locally compact groupoids. The claim is defended in this essay that human consciousness is *unique* and should be viewed as an ultra-complex, global process of processes, at a *meta-level* not sub–summed by, but compatible with, human brain dynamics. The emergence of consciousness and its existence are considered to be dependent upon an extremely complex structural and functional unit with an asymmetric network topology and connectivities–the human brain. However, the appearance of human consciousness is shown to be critically dependent upon societal co-evolution, elaborate language-symbolic communication and 'virtual', higher dimensional, non–commutative processes involving separate space and time perceptions. Therefore, philosophical and psychological theories of the mind are approached from the theory of levels and ultra-complexity viewpoints which throw new light on previous representational hypotheses and proposed semantic models in cognitive science. Anticipatory systems and complex causality at the top levels of reality are discussed in the context of the ontological theory of levels with its complex/entangled/intertwined ramifications in psychology, sociology and ecology. A paradigm shift towards *non-commutative*, or more generally, non-Abelian theories of highly complex dynamics is suggested to unfold now in physics, mathematics, life and cognitive sciences, thus leading to the realizations of higher dimensional algebras in neurosciences and psychology, as well as in human genomics, bioinformatics and interactomics. The presence of strange attractors in modern society dynamics gives rise to very serious concerns for the future of mankind and the continued persistence of a multi-stable Biosphere.

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1991 *Mathematics Subject Classification.* Categorical Ontology; Theoretical Biology; Non–Abelian Algebraic Topology; Higher Dimensional Algebra of Networks; Higher Homotopy–General van Kampen theorems; Quantum Algebraic Topology; Quantum Double Groupoids; Rosetta and Variable Groupoids; Super–Complex and Ultra–Complex System Dynamics.

Key words and phrases. Space, Time, and SpaceTime (ST); ST in Automata vs. Quantum Automata and Organisms; Categorical Ontology and the Theory of Levels; Relational Biology Principles; What is Life and Life's multiple Logics, LM- and Q- Logic; Organismic Categories and Relational Patterns; Abelian vs. Non-Abelian theories; Commutativity restrictions in Logics, Mathematics, Physics and Emergent Systems; Łukasiewicz-Moisil Logic Algebras of Genetic Networks and Interactomes;*Homo sapiens*; the emergence of hominins and hominoides; cognitive science; mental representations and intentionality; Brentano, Harman, Dennett, Field and Fodor's philosophy of the mind; Higher Dimensional Algebra of Brain Functions; Higher Homotopy-General Van Kampen Theorems (HHvKT) and Non-Abelian Algebraic Topology (NAAT); Non-commutativity of Diagrams and Non-Abelian Theories; Non-Abelian Categorical Ontology; non-commutative topological invariants of complex dynamic state spaces; Natural Transformations in Molecular and Relational Biology; molecular class variables (mcv); the Primordial MR and *Archea* unicellular organisms; Evolution and local-to-global procedures; biogroupoids; variable groupoids, variable categories, variable topology and atlas structures; irreversibility and open systems; selective boundaries vs. horizons; universal temporality; Super-Complex Systems; Global and Local aspects of Biological Evolution; Colimits of Variable Biogroupoids; Chains and Compositions of Local Procedures (COLPs) in the Evolution and Co-evolution of Species; What is Consciousness and Synaesthesia ?; Human Consciousness and Brain Dynamics as non-Abelian Ultra-Complex Processes; Emergence of Human Consciousness through Co-evolution; Social interactions; objectivation and memes; anticipation and feedforward processes; systems of internal representations; propositional attitudes and sentence-analogs; moral duality and strange attractors of modern society dynamics.

Contents

1. Introduction.

Ontology has acquired over time several meanings, and it has also been approached in many different ways, however these are all connected to the concepts of an *'objective existence'* and categories of items. We shall consider here the noun *existence* as a basic concept which cannot be defined in either simple or atomic terms, with the latter in the sense of Wittgenstein. Furthermore, generating *meaningful classifications of items* that belong to the objective reality is a major task of ontology. Without any doubt, however, the most interesting question by far is how human consciousness emerged subsequent only to the emergence of *H. sapiens*, his speech-syntactic language and an appropriately organized primitive society of humans. No doubt, the details of this highly complex process have been the subject of intense controversies over the last several centuries, which will continue as long as essential data remains either scarce or unattainable.

Our intended readers are both philosophers and scientists interested in Ontology and the philosophy of science. We do not lay claim in this essay to elucidate any of the fundamental problems of Ontology, such as the question of existence of an essence for every ontological item, or indeed how highly complex systems or 'items' have come into existence. We are enquiring instead if new methodological tools may be brought to bear, and can be indeed further developed to address fundamental spacetime ontology problems. We then proceed to investigate the close relationships between the theory of levels recently developed by Poli (2001, 2006, 2008) and the highly complex dynamics encountered in 'natural, adaptive systems' such as organisms, the human brain, the mind and human societies. The 'right kind of tools' for such ontology developments must be both precise and flexible in order to allow successful ontological enquiries into the fundamental problems of complexity. As we are now at a new stage of development in philosophy, science and especially ontology, such tools are beginning to emerge from, or are

indeed in the process of being developed as a result of trends towards *unity* in logics, mathematics and physics. As a major goal of philosophy is to provide a *'synthesis of syntheses'* (cf. Herbert Spencer in 1862), there is an established need in ontology for a critical selection of the most general concepts, going beyond the fields of interest of all special sciences; this leads also to a critical reconsideration of the essential levels of 'objective reality'. The challenges that one must face are so great that one cannot accept on an *a priori* basis (e.g., Platonic, Aristotelian, Kantian, Wittgensteinian, etc.) any theses, axioms or even assumptions that may not be decidable rationally if reliable conclusions are to be drawn through logical inference. Recent trends in mathematics are towards greater unity and emphasis on the use of intuitionistic logic, such as Brouwer-Heyting logic (as shown in further detail in the recent report of Brown, Glazebrook and Baianu, 2007), and also of many-valued logics (Georgescu, 2006) in defining universal mathematical concepts. It is interesting to note here that in Greek, and later in Roman, antiquity both philosophers and orators did link philosophy only to chrysippian, or binary logic. Moreover, in medieval times, at first Francis Bacon, then Newton opted for quite precise formulations of "natural philosophy", and also to a logical approach to objective reality. However, subsequent philosophical developments have not been limited to such precise formulations and, indeed, mathematical developments may seem to have had much less impact on philosophy after Descartes, Leibnitz, Newton and Kant than in their time. On the other hand, this was not, and is not, the case in the development of logic, metatheories and metalogics which have been strongly influenced and enhanced by mathematics and metamathematics.

The authors aim at a concise presentation of novel methodologies for studying the difficult, as well as the controversial, ontological problem of Space and Time at different levels of objective reality defined here as Complex, Super–Complex and Ultra–Complex Dynamic Systems. These are biological organisms, societies, and more generally, systems that are not recursively–computable. Rigorous definitions of the logical and mathematical concepts employed here, as well as a step-by-step construction of our conceptual framework, were provided in a recent series of publications on categorical ontology of levels and complex systems dynamics (Baianu et al, 2007 a–c; Brown et al, 2007). The continuation of the very existence of human society may now depend on an improved understanding of highly complex systems and the mind, and how the global human society interacts with the rest of the biosphere and its natural environment. It is most likely that such tools that we shall suggest here might have value not only to the sciences of complexity and ontology but, more generally also, to all philosophers seriously interested in keeping on the rigorous side of the fence in their arguments. Following Kant's critique of 'pure' reason and Wittgenstein' s critique of language misuse in philosophy, one needs also to critically examine the possibility of using general and universal, mathematical language and tools in formal approaches to ontology. Throughout this essay we shall use the attribute *'categorial'* only for philosophical and linguistic arguments. On the other hand, we shall utilize the rigorous term *'categorical'* only in conjunction with applications of concepts and results from the more restrictive, but still general, mathematical *Theory of Categories, Functors and Natural Transformations* (TC-FNT). According to SPE (2006): "Category theory ... is a general mathematical **theory of structures and of systems of structures**. *Category theory is both an interesting object of philosophical study, and a potentially powerful formal tool for philosophical investigations of concepts such as space, system, and even truth... It has come to occupy a central position in contemporary mathematics and theoretical computer science, and is also applied to mathematical physics.*" Traditional, modern philosophy– considered as a search for improving knowledge and wisdom– does also aims at unity that might be obtained as suggested by Herbert Spencer in 1862 through a *'synthesis of syntheses'*; this could be perhaps iterated many times because each treatment is based upon a critical evaluation and provisional improvements of previous treatments or stages. One notes however that this methodological question is hotly debated by modern philosophers beginning, for example, by Descartes before Kant and Spencer; Descartes championed with a great deal of success the '*analytical'* approach in which *all* available evidence is, in principle, examined critically and skeptically first both by the proposer of novel metaphysical claims and his, or her, readers. Descartes equated the 'synthetic' approach with the Euclidean 'geometric' (axiomatic) approach, and thus relegated synthesis to a secondary, perhaps less significant, role than that of critical *analysis* of scientific 'data' input, such as the laws, principles, axioms and theories of all specific sciences. Spinoza's, Kant's and Spencer's styles might be considered to be synthetic by Descartes and all Cartesians, whereas Russell's approach might also be considered to be analytical. Clearly and correctly, however, Descartes did not regard analysis (A) and synthesis (S) as exactly inverse to each other, such as $A \rightleftarrows S$, and also not merely as 'bottom–up' and 'top–bottom' processes ($\downarrow\uparrow$). Interestingly, unlike Descartes' discourse of the philosophical method, his treatise of philosophical principles comes closer to the synthetic approach in having definitions and deductive attempts, logical inferences, not unlike his 'synthetic' predecessors, albeit with completely different claims and perhaps a wider horizon. The reader may immediately note that if one, as proposed by Descartes, begins the presentation or method with an analysis A, followed by a synthesis S, and then reversed the presentation in a follow-up treatment by beginning with a synthesis $S*$ followed by an analysis $A*$ of the predictions made by $S*$ consistent, or analogous, with A, then obviously $AS \neq$ S*A* because we assumed that $A \simeq A*$ and that $S \neq S*$. Furthermore, if one did not make any additional assumptions about analysis and synthesis,

then $analysis \rightarrow synthesis \neq synthesis \rightarrow analysis$, or $AS \neq SA$, that is analysis and synthesis obviously '*do not commute*'; such a theory when expressed mathematically would be then called '*non-Abelian*'. This is also a good example of the meaning of the term non-Abelian in a philosphical, epistemological context.

2. The Theory of Levels in Categorial and Categorical Ontology.

This section outlines our novel methodology and approach to the ontological theory of levels, which is then applied in subsequent sections in a manner consistent with our recently published developments (Baianu et al 2007a,b,c; Brown et al 2007), and also with the papers by Poli (2008) and Baianu and Poli (2008), in this volume. Here, we are in harmony with the theme and approach of the ontological theory of levels of reality (Poli, 1998, 2001, 2008) by considering both philosophical–categorial aspects such as Kant's relational and modal categories, as well as categorical–mathematical tools and models of complex systems in terms of a dynamic, evolutionary viewpoint.

We are then presenting a categorical ontology of highly complex systems, discussing the modalities and possible operational logics of living organisms, in general. Then, we consider briefly those integrated functions of the human brain that support the ultra-complex human mind and its important roles in societies. Mores specifically, we propose to combine a critical analysis of language with precisely defined, abstract categorical concepts from Algebraic Topology (Brown et al 2007a) and the general-mathematical Theory of Categories, Functors and Natural Transformations (Eilenberg and Mac Lane 1943, 1945; Mitchell, 1968; Popescu, 1973; Mac Lane and Moerdijk, 1992; Mac Lane 2000) into a categorical framework which is suitable for further ontological development, especially in the relational rather than modal ontology of complex spacetime structures. Basic concepts of Categorical Ontology are presented in this section, whereas formal definitions are relegated to one of our recent, detailed reports (Brown, Glazebrook and Baianu, 2007). On the one hand, philosophical categories according to Kant are: *quantity, quality, relation* and *modality*, and the most complex and far-reaching questions concern the relational and modality-related categories. On the other hand, mathematical categories are considered at present as the most general and universal structures in mathematics, consisting of related *abstract objects connected by arrows.* The abstract objects in a category may, or may not, have a specified *structure*, but must all be of the same type or kind in any given category. The arrows (also called *'morphisms'*) can represent relations, mappings/functions, operators, transformations, homeomorphisms, and so on, thus allowing great flexibility in applications, including those outside mathematics as in: Logics (Georgescu 2006), Computer Science, Life Sciences (Baianu and Marinescu, 1969; Baianu, 1987; Brown and Porter, 1999; Baianu et al, 2006a; Brown et al 2007a), Psychology and Sociology (Baianu et al, 2007a). The mathematical category also has a form of *'internal' symmetry*, specified precisely as the *commutativity* of chains of morphism compositions that are uni-directional only, or as *naturality of diagrams* of morphisms; finally, any object A of an abstract category has an associated, unique, identity, 1_A, and therefore, one can replace all objects in abstract categories by the identity morphisms. (When all arrows are *invertible*, the special category thus obtained is called a *'groupoid'*, and plays a fundamental role in the field of mathematics called Algebraic Topology).

The categorical viewpoint– as emphasized by William Lawvere, Charles Ehresmann and most mathematicians– is that the key concept and mathematical structure is that of *morphisms* that can be seen, for example, as abstract relations, mappings, functions, connections, interactions, transformations, and so on. Thus, one notes here how the philosophical category of '*relation*' is closely allied to the basic concept of morphism, or arrow, in an abstract category; the implicit tenet is that arrows are what counts. One can therefore express all essential properties, attributes, and structures by means of arrows that, in the most general case, can represent either philosophical 'relations' or modalities, the question then remaining if philosophical–categorial properties need be subjected to the categorical restriction of *commutativity.* As there is no *a priori* reason in either nature or 'pure' reasoning, including any form of Kantian 'transcedental logic', that either relational or modal categories should in general have any symmetry properties, one cannot impose onto philosophy, and especially in ontology, all the strictures of category theory, and especially commutativity. Interestingly, the same critique and comment applies to Logics: only the simplest forms of Logics, the Boolean and intuitionistic, Heyting-Brouwer logic algebras are commutative, whereas the algebras of many-valued (MV) logics, such as Łukasiewicz logic are *non-commutative*, (or *non-Abelian*). These ideas about the non-Abelian character of general philosophical and logical theories, including general ontology approaches, will be considered next in further detail.

2.1. **Basic Structure of Categorical Ontology and the Theory of Levels. Emergence of Higher Levels, Meta–Levels and Their Sublevels.** With the provisos specified above, our proposed methodology and approach employs concepts and mathematical techniques from Category Theory which afford describing the characteristics and binding of ontological levels besides their links with other theories. Whereas Hartmann (1952) stratified levels in terms of the four frameworks: physical, 'organic'/biological, mental and spiritual, we restrict here mainly to the first three. The categorical techniques which we introduce provide a powerful means for describing levels in both a linear and interwoven fashion, thus leading to the necessary bill of fare: emergence, complexity and open non-equilibrium,

or irreversible systems. Furthermore, an effective approach to Philosophical Ontology is concerned with *universal items* assembled in categories of objects and relations, involving, in general, transformations and/or processes. Thus, Categorical Ontology is fundamentally dependent upon both space and time considerations. Therefore, one needs to consider first a dynamic classification of systems into different levels of reality, beginning with the physical levels (including the fundamental quantum level) and continuing in an increasing order of complexity to the chemical–molecular levels, and then higher, towards the biological, psychological, societal and environmental levels. Indeed, it is the principal tenet in the theory of levels that : "*there is a two-way interaction between social and mental systems that impinges upon the material realm for which the latter is the bearer of both"* (Poli, 2001). Thus, any effective Categorical Ontology approach requires, or generates–in the constructive sense–a '***structure***' or pattern rather than a discrete set of items. The evolution in our universe is thus seen to proceed from the level of 'elementary' quantum 'wave–particles', their interactions *via* quantized fields (photons, bosons, gluons, etc.), also including the quantum gravitation level, towards aggregates or categories of increasing complexity. In this sense, the classical macroscopic systems are defined as 'simple' dynamical systems that are computable recursively as numerical solutions of mathematical systems of either ordinary or partial differential equations. Underlying such mathematical systems is always the Boolean, or chrysippian, logic, namely, the logic of sets, Venn diagrams, digital computers and perhaps automatic reflex movements/motor actions of animals. The simple dynamical systems are always recursively computable (see for example, Suppes, 1995–2007), and in a certain specific sense, both degenerate and *non-generic*,consequently also *structurally unstable* to small perturbations. The next higher order of systems is then exemplified by 'systems with chaotic dynamics' that are conventionally called 'complex' by physicists, computer scientists and modelers even though such physical, dynamical systems are still completely deterministic. It has been formally proven that such systems are *recursively non-computable* (see for example, Baianu, 1987 for a 2-page, rigorous mathematical proof and relevant references), and therefore they cannot be completely and correctly simulated by digital computers, even though some are often expressed mathematically in terms of iterated maps or algorithmic-style formulas. Higher level systems above the chaotic ones, that we shall call *'Super–Complex, Biological systems'*, are the living organisms, followed at still higher levels by the *ultra-complex 'systems'* of the human mind and human societies that will be discussed in the last section. The evolution to the highest order of complexity- the ultra-complex, meta–'system' of processes–the human mind–may have become possible, and indeed accelerated, only through human societal interactions and effective, elaborate/rational and symbolic communication through speech (rather than screech (as in the case of chimpanzees, gorillas, baboons, etc).

2.1.1. *Fundamental Concepts of Algebraic Topology with Potential Application to Ontology Levels Theory and Space-Time Structures.* We shall consider in this section the potential impact of novel Algebraic Topology concepts, methods and results on the problems of defining and classifying rigorously Quantum Spacetimes (QSS). The 600-page manuscript, *'Pursuing Stacks'* by Alexander Grothendieck (1983) was aimed at a *non-Abelian homological algebra*; it did not achieve this goal but has been very influential in the development of weak n-categories and other *higher categorical structures* that are relevant to QSS structures. With the advent of Quantum Groupoids–generalizing Quantum Groups, Quantum Algebra and Quantum Algebraic Topology, several fundamental concepts and new theorems of Algebraic Topology may also acquire an enhanced importance through their potential applications to current problems in theoretical and mathematical physics, such as those described in an available preprint (Baianu, Brown and Glazebrook, 2008), and also in several recent publications (Baianu et al 2007a,b; Brown et al 2007). In such novel applications, both the internal and external groupoid symmetries (Weinstein, 1996) may acquire new physical significance. Thus, if quantum theories were to reject the notion of a *continuum*, then it would also have to reject the notion of the real line and the notion of a path. How then is one to construct a homotopy theory? One possibility is to take the route signalled by Čech, and which later developed in the hands of Borsuk into 'Shape Theory' (see, Cordier and Porter, 1989). Thus a quite general space is studied by means of its approximation by open covers. Yet another possible approach is briefly pointed out in the next section.

A few fundamental concepts of Algebraic Topology and Category Theory will be introduced here next so that we can reach an extremely wide range of applicability, especially to the higher complexity levels of reality. Full mathematical details are however available in a recent paper by Brown et al. (2007) that focused on a mathematical–conceptual framework for a formal approach to categorical ontology and the theory of levels.

Groupoids, Topological Groupoids, Groupoid Atlases and Locally Lie Groupids.

Recall that a *groupoid* G is a small category in which every morphism is an isomorphism.

Topological Groupoids.

An especially interesting concept is that of a *topological groupoid* which is a groupoid internal to the category Top ; further mathematical details are presented in the paper by Brown et al. (2007b).

An Atlas of Groupoids.

Motivation for the notion of a groupoid atlas comes from considering families of group actions, in the first instance on the same set. As a notable instance, a subgroup H of a group G gives rise to a group action of H on G whose orbits are the cosets of H in G. However a common situation is to have more than one subgroup of G, and then the various actions of these subgroups on G are related to the actions of the intersections of the subgroups. This situation is handled by the notion of *global action*, as defined in Bak (2000). A key point in this construction is that the orbits of a group action then become the connected components of a groupoid. Also this enables relations with other uses of groupoids. The above account motivates the following. A *groupoid atlas* $\mathcal{A}$ on a set $X_{\mathcal{A}}$ consists of a family of 'local groupoids' $(\mathsf{G}_{\mathcal{A}})$ defined with respective object sets $(X_{\mathcal{A}})_\alpha$ taken to be subsets of $X_{\mathcal{A}}$. These local groupoids are indexed by a set $\Psi_{\mathcal{A}}$, again called the *coordinate system of* $\mathcal{A}$ which is equipped with a reflexive relation denoted by $\leqslant$. This data is to satisfy several conditions (Bak et al., 2006), as completely specified in Brown et al (2007).

The van Kampen Theorem and Its Generalizations to Groupoids and Higher Homotopy

The van Kampen Theorem has an important and also anomalous rôle in algebraic topology. It allows computation of an important invariant for spaces built up out of simpler ones. It is anomalous because it deals with a non-Abelian invariant, and has not been seen as having higher dimensional analogues. However, Brown (1967) found a generalisation of this theorem to groupoids, as follows. In this, $\pi_1(X, X_0)$ is the *fundamental groupoid* of X on a set X_0 of base points: so it consists of homotopy classes rel end points of paths in X joining points of $X_0 \cap X$. Such methods were extended successfully by R. Brown to *higher dimensions*. The Higher Homotopy van Kampen Theorem is discussed in the accompanying paper by Brown, Glazebrook and Baianu (2007).

2.2. **Local-to-Global Problems in Spacetime Structures. Symmetry Breaking, Irreversibility and the Emergence of Highly Complex Dynamics.**

2.2.1. *Spacetime Local Inhomogeneity, Discreteness and Broken Symmetries: From Local to Global Structures.* On summarizing in this section the evolution of the physical concepts of space and time, we are pointing out first how the views changed from homogeneity and continuity to *inhomogeneity and discreteness*. Then, we link this paradigm shift to a possible, novel solution in terms of local-to-global approaches and procedures to spacetime structures. These local-to-global procedures procedures will therefore lead to a wide range of applications sketched in the later sections, such as the *emergence of higher dimensional spacetime* structures through highly complex dynamics in organismic development, adaptation, evolution, consciousness and society interactions.

Classical physics, including GR involves a concept of both *continuous* and *homogeneous* space and time with strict causal (mechanistic) evolution of all physical processes ("*God does not play dice*", cf. Albert Einstein). Furthermore, up to the introduction of *quanta–discrete* portions, or packets–of energy by Ernst Planck (which was further elaborated by Einstein, Heisenberg, Dirac, Feynman, Weyl and other eminent physicists of the last century), energy was also considered to be a continuous function, though not homogeneously distributed in space and time. Einstein's Relativity theories joined together space and time into one 'new' entity–the concept of *spacetime*. In the improved form of GR, inhomogeneities caused by the presence of matter are also allowed to occur in spacetime. Causality, however, remained *strict*, but also more complicated than in the Newtonian theories as discontinuities appear in spacetime in the form of singularities, or 'black holes. The standard GR theory, the Maxwellian Theory of Electromagnetism and Newtonian mechanics can all be considered *Abelian*, even though GR not only allows, but indeed, requires spacetime inhomogeneities to occur in the presence of gravitational fields, unlike Newtonian mechanics *where space is both absolute homogeneous. Recent efforts to develop non-Abelian* GR theories–especially with an intent to develop Quantum Gravity theories– seem to have considered both possibilities of locally homogeneous or inhomogeneous, but still globally continuous spacetimes. The successes of non-Abelian gauge theories have become well known in physics since 1999, but they still await the experimental discovery of their predicted Higgs boson particles.

Although Einstein's Relativity theories incorporate the concept of *quantum of energy*, or photon, into their basic structures, they also deny such discreteness to spacetime even though the discreteness of energy is obviously accepted within Relativity theories. The GR concept of spacetime being modified, or *distorted/'bent'*, by matter goes further back to Riemann, but it was Einstein's GR theory that introduced the idea of representing gravitation as the result of *spacetime distortion by matter.* Implicitly, such spacetime distortions remained continuous even though the gravitational field energy –as all energy– was allowed to vary in *discrete*, albeit very tiny portions–the gravitational quanta. So far, however, the detection of gravitons –the quanta of gravity–related to the spacetime distortions by matter–has been unsuccessful. Mathematically elegant/precise and physically 'validated' through several crucial experiments and astrophysical observations, Einstein's GR is obviously not reconcilable with Quantum theories (QTs). GR was designed as the *large–scale* theory of the Universe, whereas Quantum theories–at least in the beginning–were designed to address the problems of *microphysical* measurements at very tiny scales of space and time involving extremely small quanta of energy. We see therefore the QTs vs. GR as a local-to-global problem that has not been yet resolved in the form of an universally valid Quantum Gravity. Promising, partial solutions

are suggested in two recent papers (Baianu, Brown and Glazebrook, 2007b and Brown, Glazebrook and Baianu, 2007). Quantum theories (QTs) were developed that are just as elegant mathematically as GR, and they were also physically 'validated' through numerous, extremely sensitive and carefully designed experiments. However, to date quantum theories have not yet been extended, or generalized, to a form capable of recovering the results of Einstein's GR as a quantum field theory over a GR-spacetime altered by gravity. Furthermore, quantum symmetries occur not only on microphysical scales, but also macroscopically in certain, 'special' cases, such as liquid ^{3}He close to absolute zero and superconductors where *extended coherence* is possible for the superfluid, Cooper electron-pairs. Explaining such phenomena requires the consideration of *symmetry breaking* (Weinberg, 2003). Occasionally, symmetry breaking is also invoked as a 'possible mechanism for human consciousness' which also seems to involve some form of 'global coherence'–over most of the brain; however, the existence of such a '*quantum* coherence in the brain'–at room temperature–as it would be precisely required/defined by QTs, is a most unlikely event. On the other hand, a *quantum symmetry breaking* in a neural network considered metaphorically as a Hopfield ('spin-glass') network might be conceivable close to physiological temperatures but for the lack of existence of any requisite (electron ?) spin lattice structure which is indeed an absolute requirement in such a spin-glass metaphor–if it is to be taken at all seriously!

Now comes the real, and very interesting part of the story: neuronal networks do form functional patterns and structures that possess partially 'broken', or more general symmetries than those described by quantum groups. Such *extended symmetries* can be mathematically determined, or specified, by certain *groupoids*–that were previously called *'neuro-groupoids'.* Even more generally, genetic networks also exhibit extended symmetries represented for an organismal species by a *biogroupoid* structure, as previously defined and discussed by Baianu, Brown, Georgescu and Glazebrook (2006). Such biogroupoid structures can be experimentally validated, for example, at least partially through Functional Genomics observations and computer, bioinformatics processing (Baianu, 2007). We shall discuss further several such interesting groupoid structures in the following sections, and also how they have already been utilized in local-to-global procedures to construct 'global' solutions; such global solutions in quite complex (holonomy) cases can still be *unique* up to an isomorphism (*the Globalization Theorem*, as to be discussed in Brown, Glazebrook and Baianu, 2007). Last-but-not-least, *holonomy* may provide a global solution, or 'explanation' for 'memory storage by 'neuro-groupoids'. Uniqueness holonomy theorems might possibly 'explain' unique, persistent and resilient memories.

2.2.2. *Towards Biological Postulates and Principles.* Whereas the hierarchical theory of levels provides a powerful, systems approach through categorical ontology, the foundation of science involves *universal* models and theories pertaining to different levels of reality. It would seem natural to expect that theories aimed at different ontological levels of reality should have different principles. We are advocating the need for developing precise, but nevertheless 'flexible', concepts and novel mathematical representations suitable for understanding the emergence of the higher complexity levels of reality. Such theories are based on axioms, principles, postulates and laws operating on distinct levels of reality with a specific degree of complexity. Because of such distinctions, inter-level principles or laws are rare and over-simplified principles abound. Alternative approaches may be, however, possible based upon an improved ontological theory of levels. Interestingly, the founder of Relational Biology, Nicolas Rashevsky (1968) proposed that physical laws and principles can be expressed in terms of *mathematical functions*, or mappings, and are thus being predominantly expressed in a *numerical* form, whereas the laws and principles of biological organisms and societies need take a more general form in terms of quite general, or abstract–mathematical and logical relations which cannot always be expressed numerically; the latter are often qualitative, whereas the former are predominantly quantitative. In this context, one may also suggest that modern, Abstract Art, in its various forms– if considered as a distinct class of representations–has moved ahead of modern philosophy to attempt universal representations of reality in a precise but flexible manner, thus appealing to both reason and emotions combined.

Rashevsky focused his Relational Biology/Society Organization papers on a search for more general relations in Biology and Sociology that are also compatible with the former. Furthermore, Rashevsky proposed two biological principles that add to Darwin's natural selection and the 'survival of the fittest principle', *the emergent relational structure that are defining the adaptive organism*:

1. **The Principle of Optimal Design**, and
2. **The Principle of Relational Invariance** (phrased by Rashevsky as *"Biological Epimorphism"*).

In essence, the 'Principle of Optimal Design' defines the organization and structure of the 'fittest' organism which survives in the natural selection process of competition between species, in terms of an extremal criterion, similar to that of Maupertuis; the optimally 'designed' organism is that which acquires maximum functionality essential to survival of the successful species at the lowest 'cost' possible. The 'costs' are defined in the context of the environmental niche in terms of material, energy, genetic and organismic processes required to produce/entail the

pre-requisite biological function(s) and their supporting anatomical structure(s) needed for competitive survival in the selected niche. Further details were presented by Robert Rosen in his short but significant book on optimality (1970).

The 'Principle of Biological Epimorphism' on the other hand states that the highly specialized biological functions of higher organisms can be mapped (through an epimorphism) onto those of the simpler organisms, and ultimately onto those of a (hypothetical) primordial organism (which was assumed to be unique up to an isomorphism or *selection-equivalence*). The latter proposition, as formulated by Rashevsky, is more akin to a postulate than a principle. However, it was then generalized and re-stated as the Postulate of Relational Invariance (Baianu, Brown, Georgescu and Glazebrook, 2006). Somewhat similarly, a dual principle and colimit construction was invoked for the ontogenetic development of organisms (Baianu, 1970).

An axiomatic system (ETAS) leading to higher dimensional algebras of organisms in supercategories has also been formulated (Baianu, 1970) which specifies both the logical and the mathematical ($\pi-$) structures required for complete self-reproduction and self-reference, self-awareness, etc., of living organisms. To date there is no higher dimensional algebra (HDA) axiomatics other than the ETAS proposed for complete self-reproduction in super-complex systems, or for self-reference in ultra-complex ones. On the other hand, the preceding, simpler ETAC axiomatics, was proposed for the foundation of 'all' mathematics, including categories (Lawvere, 1966, 1968), but this seems to have occurred before the emergence of HDA.

2.3. **Towards a Formal Theory of Levels.** This subsection will introduce in a concise manner fundamental concepts of the ontological theory of levels. Further details are reported by Poli (2001, 2008) and Baianu and Poli (2008; in this volume.).

2.3.1. *Fundamentals of Poli's Theory of Levels.* The ontological theory of levels (Poli, 2001, 2006a,b; 2008) considers a hierarchy of *items* structured on different levels of reality/existence, with the higher levels *emerging* from the lower, but usually *not* reducible to the latter, as claimed by widespread reductionism. This approach modifies and expands considerably the previous work by Hartmann (1935,1952), both in its vision and the range of possibilities. Thus, Poli (1998–2008) considers four realms or *levels* of reality: Material-inanimate/Physico-chemical, Material-living/Biological, Psychological and Social. Poli (2006a) has stressed a need for understanding *causal and spatiotemporal* phenomena formulated within a *descriptive categorical context* for theoretical levels of reality. There There is the need in this context to develop a *synthetic* methodology in order to compensate for the critical ontic data analysis, although one notes (cf. Rosen, 2001) that analysis and synthesis are not the exact inverse of each other. At the same time, we address in categorical form the *internal dynamics*, the *temporal rhythm, or cycles*, and the subsequent unfolding of reality. The genera of corresponding concepts such as 'processes', 'groups', 'essence', 'stereotypes', and so on, can be simply referred to as *'items'* which allow for the existence of many forms of causal connection (Poli, 2007). The implicit meaning is that the *irreducible multiplicity* of such connections converges, or it is ontologically integrated within a *unified synthesis*.

2.3.2. *The Object-based Approach vs Process-based (Dynamic) Ontology.* In classifications, such as those developed over time in Biology for organisms, or in Chemistry for chemical elements, the *objects* are the basic items being classified even if the 'ultimate' goal may be, for example, either evolutionary or mechanistic studies. An ontology based strictly on object classification may have little to offer from the point of view of its cognitive content. It is interesting that D'Arcy W. Thompson arrived in 1941 at an ontologic "*principle of discontinuity*" which "is inherent in all our classifications, whether mathematical, physical or biological... In short, nature proceeds *from one type to another* among organic as well as inorganic forms... and to seek for stepping stones across the gaps between is to seek in vain, for ever." (p.1094 of Thompson, 1994, re-printed edition).

It is often thought that the *object-oriented* approach can be readily converted into a process-based one. It would seem, however, that the answer to this question depends critically on the ontological level selected. For example, at the quantum level, *object and process become inter-mingled.* Either comparing or moving between levels, requires ultimately a *process-based* approach, especially in Categorical Ontology where relations and inter-process connections are essential to developing any valid theory. Ontologically, the quantum level is a fundamentally important starting point which needs to be taken into account by any theory of levels that aims at completeness. Such completeness may not be attainable, however, simply because an 'extension' of Gödel's theorem may hold here also. The fundamental quantum level is generally accepted to be dynamically, or intrinsically *non-commutative*, in the sense of the *non-commutative quantum logic* and also in the sense of *non-commuting quantum operators* for the essential quantum observables such as position and momentum. Therefore, any comprehensive theory of levels, in the sense of incorporating the quantum level, is thus *–mutatis mutandis– non-Abelian.* A paradigm shift towards a *non-Abelian Categorical Ontology* has already begun (Brown et al, 2007: *'Non-Abelian Algebraic Topology'*; Baianu, Brown and Glazebrook, 2006: NA-QAT; Baianu et al 2007a,b,c).

2.3.3. *From Component Objects and Molecular/Anatomical Structure to Organismic Functions and Relations: A Process–Based Approach to Ontology.* Wiener (1950,1954,1989) made the important remark that implementation of complex functionality in a (complicated) machine requires also the design and construction of a complex structure. A similar argument holds *mutatis mutandis*, or by induction, for variable machines, variable automata and variable dynamic systems (Baianu,1970 through 1986; Baianu and Marinescu, 1974); therefore, if one represents organisms as variable dynamic systems, one *a fortiori* requires a *super-complex structure* to enable or entail *super-complex dynamics*, and indeed this is the case for organisms with their extremely intricate structures at both the molecular and *supra-molecular* levels.

The essence of super– and ultra– complex systems is in the *interactions, relations and dynamic transformations* that are ubiquitous at these levels of reality. Therefore, a complete approach to ontology must clearly include *relations and interconnections* between items, with the emphasis on *dynamic processes, complexity* and *functionality* of systems. This leads one to consider general relations, such as *morphisms* on different levels, and thus to the *categorical viewpoint* of ontology. The *process-based approach* to universal ontology is therefore essential to an understanding of the ontology of levels, hierarchy, complexity, anticipatory systems, Life, Consciousness and the Universe(s). On the other hand, the opposite approach, based on objects, is perhaps useful only at the initial cognitive stages in experimental science. We note here the distinct meaning of 'object' in psychology, which is much different than the one considered in this subsection; for example, an external process can be 'reflected' in one's mind as an 'object of study'. This duality, or complementarity between 'object' and 'subject', 'objective' and 'subjective' seems to be widely adopted in philosophy, beginning with Descartes and continuing with Kant, Heidegger, and so on. A somewhat similar, but not precisely analogous distinction is fundamental in standard Quantum Theory– the distinction between the observed/measured system (which is quantum) and the measuring instrument (which is classical).

2.3.4. *Physico-chemical Structure–Function Relationships.* It is generally accepted at present that structure-functionality relationships are key to the understanding of super-complex systems such as living cells and organisms. Integrating structure–function relationships into a categorical ontology approach is a viable alternative to level reduction, and philosophical/ epistemologic reductionism in general. Such an approach is also essential to the science of complex/super-complex systems; it is also considerably more difficult than either physicalist reductionism, *abstract relationalism* or 'rhetorical mathematics'. Moreover, because there are many alternative ways in which the physico-chemical structures can be combined within an organizational map or relational complex system, there is a *multiplicity of 'solutions'* or mathematical models that needs be investigated, and the latter are not computable with a digital computer in the case of complex/super-complex systems such as organisms (Rosen 1987). The problem is further compounded by the presence of structural *disorder* (in the physical structure sense) which leads to a *multiplicity* of dynamical-physicochemical structures (or 'configurations') of a biopolymer (Baianu, 1980b); this complicates the assignment of a 'fuzzy' physico-chemical structure to a well-defined biological function unless extensive experimental data are available, as for example, those derived through computation from 2D-NMR spectroscopy data (Wütrich, 1996), or neutron/X-ray scattering and related multi-nuclear NMR spectroscopy/relaxation data (e.g. Chs. 2 to 9 in Baianu et al., 1995). Detailed considerations of the ubiquitous, partial disorder effects on the structure-functionality relationships were reported for the first time by Baianu (1980b). Specific aspects were also recently discussed by Wütrich (1996) on the basis of 2D-NMR analysis.

As befitting the situation, there are devised *universal* categories of reality in its entirety, and also subcategories which apply to the respective sub-domains of reality. We harmonize this theme by considering categorical models of complex systems in terms of an evolutionary dynamic viewpoint using the mathematical methods of category theory which afford describing the characteristics and binding of levels, besides the links with other theories which, *a priori*, are essential requirements. We also underscore a significant component of this essay that relates the ontology to geometry/topology; specifically, if a level is defined via 'iterates of local procedures' (cf 'items in iteration', Poli, 2001), that will further expanded upon in Section 3.7.2; then we have a handle on describing its intrinsic governing dynamics (with feedback). As we shall see in the next subsection, categorical techniques– which form an integral part of our ontological considerations– provide a means of describing a hierarchy of levels in both a linear and interwoven, or *entangled*, fashion, thus leading to the necessary bill of fare: emergence, higher complexity and open, non-equilibrium/irreversible systems. We must emphasize that the categorical methodology selected here is *intrinsically 'higher dimensional'*, and can thus account for meta–levels, such as 'processes between processes...' within, or between, the levels–and sub-levels– in question. Whereas a strictly Boolean classification of levels allows only for the occurrence of *discrete* ontological levels, and also does not readily accommodate either *contingent* or *stochastic sub-levels*, the LM-logic algebra is readily extended to *continuous*, *contingent* or even *fuzzy* (Baianu and Marinescu, 1968) sub-levels, or levels of reality (cf. Georgescu, 2006; Baianu, 1977, 1987; Baianu, Brown, Georgescu and Glazebrook, 2006). Clearly, a Non-Abelian Ontology of Levels would require the inclusion of either Q- or LM-

logics algebraic categories (discussed next in Section 3.1) because it begins at the fundamental quantum level –where Q-logic reigns– and 'rises' to the emergent ultra-complex level(s) with 'all' of its possible sub-levels represented by certain LM-logics. (Further considerations on the meta–level question are presented in Baianu and Poli, 2008). On each level of the ontological hierarchy there is a significant amount of connectivity through inter-dependence, interactions or general relations often giving rise to complex patterns that are not readily analyzed by partitioning or through stochastic methods as they are neither simple, nor are they random connections. This ontological situation gives rise to a wide variety of networks, graphs, and/or mathematical categories, all with different connectivity rules, different types of activities, and also a hierarchy of super-networks of networks of subnetworks. Then, the important question arises *what types of basic symmetry or patterns* such super-networks of items can have, and how do the effects of their sub-networks percolate through the various levels. From the categorical viewpoint, these are of two basic types: they are either *commutative* or *non-commutative*, where, at least at the quantum level, the latter takes precedence over the former, as we shall further discuss and explain in the following sections.

3. Categorical Representations of the Ontological Theory of Levels: From Simple to Super– and Ultra– Complex Dynamic Systems. Abelian vs. Non-Abelian Theories.

General system analysis seems to require formulating ontology by means of categorical concepts (Poli, 2007, TAO-1; Baianu and Poli, 2007). Furthermore, category theory appears as a natural framework for any general theory of transformations or dynamic processes, just as group theory provides the appropriate framework for classical dynamics and quantum systems with a finite number of degrees of freedom. Therefore, we have adopted a categorical approach as the starting point, meaning that we are looking for *"what is universal"* (in some domain, or in general), and that only for simple systems this involves *commutative* modelling diagrams and structures (as, for example, in Figure 1 of Rosen, 1987). Note that this ontological use of the word *'universal'* is quite distinct from the mathematical use of *'universal property'*, which means that a property of a construction on particular objects is defined by its relation to *all* other objects (i.e., it is a *global* attribute), usually through constructing a morphism, since this is the only way, in an *abstract* category, for objects to be related. With the first (ontological) meaning, the most universal feature of reality is that it is *temporal*, i.e. it changes, it is subject to countless transformations, movements and alterations. In this select case of *universal temporality*, it seems that the two different meanings can be brought into superposition through appropriate formalization. Furthermore, *concrete* categories may also allow for the representation of ontological 'universal items' as in certain previous applications to categories of neural networks (Baianu, 1972; 1987; Baianu et al 2006, 2007a). For general categories, however, each object is a kind of a Skinnerian black box, whose only exposure is through input and output, i.e. the object is given by its *connectivity* through various morphisms, to other objects. For example, the dual of the category of sets still has objects but these have *no structure* (from the categorical viewpoint). Other types of category are important as expressing useful relationships on structures, for example *lextensive* categories, which have been used to express a general van Kampen theorem by Brown and Janelidze (1997).

Thus, abstract mathematical structures are developed to define *relationships*, to deduce and calculate, to exploit and define analogies, since *analogies are between relations* between things rather than between things themselves. A description of a new structure is in some sense a development of part of a *new language*; the notion of structure is also related to the notion of *analogy.* It is one of the triumphs of the mathematical theory of categories in the 20th century to make progress towards *unifying* mathematics through the finding of *analogies* between various behavior of structures across different areas of mathematics. This theme is further elaborated in the article by Brown and Porter (2002) which argue that many analogies in mathematics, and in many other areas, are *not* between objects themselves but *between the relations* between objects.

3.1. **Categorical Logics of Processes and Structures: Universal Concepts and Properties.**

The logic of classical events associated with either mechanical systems, mechanisms, universal Turing machines, automata, robots and digital computers is generally understood to be simple, *Boolean* logic. The same applies to Einstein's GR. It is only with the advent of quantum theories that quantum logics of events were introduced which are *non-commutative*, and therefore, also *non-Boolean.* Somewhat surprisingly, however, the connection between quantum logics (QL) and other *non-commutative* many-valued logics, such as the Łukasiewicz logic, has only been recently made (Dalla Chiara, 2004 and refs. cited therein; Baianu, 2004; Baianu et al., 2005;2006). Such considerations are also of potential interest for a wide range of complex systems, as well as quantum ones, as it has been pointed out previously (Baianu, 1977; 2004; Baianu et al, 2005;2006). Furthermore, both the concept of 'Topos' and that of variable category, can be further generalized by the involvement of *many-valued* logics, as for example in the case of 'Łukasiewicz-Moisil, or LM Topos' (Baianu et al., 2005). This is especially relevant for the development of *non-Abelian dynamics* of complex and super-complex systems; it may also be essential for understanding human consciousness (as it will be discussed in the context of Section 4).

3.1.1. *Quantum Logics (QL), Logical Lattice Algebras (LLA) and Łukasiewicz Quantum Logic (LQL).* As pointed out by von Neumann and Birkhoff (1930), a logical foundation of quantum mechanics consistent with quantum algebra is essential for the internal consistency of the theory. Such a non-traditional logic was initially formulated by von Neumann and Birkhoff (1932) and called 'Quantum Logic'. Subsequent research on Quantum Logics (Chang, 1958; Genoutti, 1968; Dalla Chiara, 1968, 2004) resulted in several approaches that involve several types of non-distributive lattice (algebra) for n–valued quantum logics. Thus, modifications of the Łukasiewicz Logic Algebras that were introduced in the context of algebraic categories by Georgescu and Popescu (1968), followed by Georgescu and Vraciu (1970) with a characterization of LM-algebras, also recently being reviewed and expanded by Georgescu (2006), can provide an appropriate framework for representing quantum systems, or– in their unmodified form- for describing the activities of complex networks in categories of Łukasiewicz Logic Algebras (Baianu, 1977). There is a logical inconsistency between the quantum algebra and the Heyting logic algebra of a standard topos as a candidate for quantum logic (Baianu et al 2007b). Furthermore, quantum algebra and topological approaches that are ultimately based on set-theoretical concepts and differentiable spaces (manifolds) also encounter serious problems of internal inconsistency. There is a basic logical inconsistency between quantum logic–which is not Boolean–and the Boolean logic underlying all differentiable manifold approaches that rely on continuous spaces of points, or certain specialized sets of elements. A possible solution to such inconsistencies is the definition of a generalized 'topos'–like concept, such as a *Quantum, Extended Topos* concept which is consistent with both Quantum Logic and Quantum Algebras (Alfsen and Schultz, 2003), being thus suitable as a framework for unifying quantum field theories and modelling in complex systems biology.

Lattices and Von Neumann-Birkhoff (VNB) Quantum Logic: Definition and Some Logical Properties.

We commence here by giving the set-based definition of a lattice. An *s–lattice* **L**, or a 'set-based' lattice, is defined as a *partially ordered set* that has all binary products (defined by the s–lattice operation " $\bigwedge$") and coproducts (defined by the s–lattice operation "$\bigvee$ "), with the "partial ordering" between two elements X and Y belonging to the s–lattice being written as "$X \preceq Y$". The partial order defined by $\preceq$ holds in **L** as $X \preceq Y$ if and only if $X = X \bigwedge Y$ (or equivalently, $Y = X \bigvee Y$ Eq.(3.1)(p. 49 of Mac Lane and Moerdijk, 1992). A *lattice* can also be defined as a *category* (see, for example: Lawvere, 1966; Baianu, 1970; Baianu et al., 2004b) subject to all ETAC axioms– but not subject, in general, to the Axiom of Choice usually encountered with sets relying on (distributive) Boolean Logic)– as well as 'partial ordering' properties, $\preceq$.

Łukasiewicz-Moisil (LM) Quantum Logic (LQL) and Algebras. Quantum Algebras (Majid, 1995, 2002) involve detailed studies of the properties and representations of Quantum State Spaces (QSS; see for example, Alfsen ans Schultz, 2003). With all truth 'nuances' or assertions of the type $<<$ *system A* is excitable to the i-th level and system B is excitable to the j-th level $>>$ one can define a special type of lattice that subject to the axioms introduced by Georgescu and Vraciu (1970) becomes a *n-valued Łukasiewicz-Moisil, or LM, Algebra.* Further algebraic and logic details are provided in Georgescu (2006) and Baianu et al (2007b). In order to have the n-valued Łukasiewicz Logic Algebra represent correctly the observed behaviours of quantum systems (that involve a quantum system interactions with a measuring instrument –which is a macroscopic object) several of the LM–algebra axioms have to be significantly changed so that the resulting lattice becomes *non-distributive* and also (possibly) *non–associative* (Dalla Chiara, 2004). With an appropriately defined quantum logic of events one can proceed to define Hilbert and von Neumann/ C*–algebras, etc, in order to be able to utilize the 'standard' procedures of quantum theories (precise definitions of these fundamental quantum algebraic concepts were presented in Baianu et al, 2007b). On the other hand, for classical systems, modelling with the unmodified Łukasiewicz Logic Algebra can also include both stochastic and fuzzy behaviours. For an example of such models the reader is referred to a previous publication (Baianu, 1977) modelling the activities of complex genetic networks from a classical standpoint. One can also define as in (Georgescu and Vraciu, 1970) the 'centers' of certain types of LM, n-valued Logic Algebras; then one has the following important theorem for such Centered Łukasiewicz n-Logic Algebras which actually defines an equivalence relation.

Theorem 3.1. The Adjointness Theorem (Georgescu and Vraciu, 1970).

*There exists an Adjointness between the Category of Centered Łukasiewicz n-Logic Algebras, **CLuk**–n, and the Category of Boolean Logic Algebras (**Bl**).*

Remark 3.1. The natural equivalence logic classes defined by the adjointness relationships in the above Adjointness Theorem define a fundamental, *'logical groupoid'* structure.

Remark 3.2. In order to adapt the standard Łukasiewicz Logic Algebra to the appropriate Quantum Łukasiewicz Logic Algebra, LQL, a few axioms of LM-algebra need modifications, such as : $N(N(X)) = Y \neq X$ (instead of the restrictive identity $N(N(X)) = X$, whenever the context, or 'measurement preparation' interaction conditions for quantum systems are incompatible with the standard 'negation' operation N of the Łukasiewicz Logic Algebra;

the latter remains however valid for the operation/ dynamics of classical or semi–classical systems, such as various complex networks with n-states (cf. Baianu, 1977). Further algebraic and conceptual details are provided in a rigorous review by Georgescu (2006), and also in the recently published reports by Baianu et al (2007b) and Brown et al. (2007).

3.2. **A Hierarchical, Formal Theory of Levels. Commutative and Non-Commutative Structures: Abelian Category Theory vs. Non-Abelian Theories.** Ontological classification based on items involves the organization of concepts, and indeed theories of knowledge, into a *hierarchy of categories of items at different levels of 'objective reality'*, as reconstructed by scientific minds through either a *bottom-up* (induction, synthesis, or abstraction) process, or through a *top-down* (deduction) process (Poli,2007), which proceeds from abstract concepts to their realizations in specific contexts of the 'real' world. Both modalities can be developed in a categorical framework. We discuss here only the bottom-up modality in Categorical Ontology.

One of the major goals of category theory is to see how the properties of a particular mathematical structure, say S, are reflected in the properties of the category $\mathsf{Cat}(S)$ of all such structures and of morphisms between them. Thus, the first step in category theory is that a definition of a structure should come with a definition of a morphism of such structures. Usually, but not always, such a definition is obvious. The next step is to compare structures. This might be obtained by means of a *functor* $A : \mathsf{Cat}(S) \longrightarrow \mathsf{Cat}(T)$. Finally, we want to compare such functors $A, B : \mathsf{Cat}(S) \longrightarrow \mathsf{Cat}(T)$. This is done by means of a natural transformation $\eta : A \Rightarrow B$. Here η assigns to each object X of $\mathsf{Cat}(S)$ a morphism $\eta(X) : A(X) \longrightarrow B(X)$ satisfying a commutativity condition for any morphism $a : X \longrightarrow Y$. In fact we can say that η assigns to each morphism a of $\mathsf{Cat}(S)$ a commutative square of morphisms in $\mathsf{Cat}(T)$ (as shown in Diagram 13.2 in the Brown, Glazebrook and Baianu (2007).). This notion of *natural transformation* is at the heart of category theory. As Eilenberg-Mac Lane write: "*to define natural transformations one needs a definition of functor, and to define the latter one needs a definition of category*". Also, the reader may have already noticed that 2-arrows become '3-objects' in the meta–category, or '3-category', of functors and natural transformations (Brown et al, 2007a).

One could formalize-for example as outlined in Baianu and Poli (2008, in this volume)–the hierarchy of multiple-level relations and structures that are present in biological, environmental and social systems in terms of the mathematical Theory of Categories, Functors and Natural Transformations (TC-FNT, see Brown, Glazebrook and Baianu, 2007). On the first level of such a hierarchy are the links between the system components represented as *'morphisms'* of a structured category which are subject to several axioms/restrictions of Category Theory, such as *commutativity* and associativity conditions for morphisms, functors and natural transformations. Then, on the second level of the hierarchy one considers *'functors'*, or links, between such first level categories, that compare categories without 'looking inside' their objects/system components. On the third level, one compares, or links, functors using *'natural transformations'* in a 3-category (meta-category) of functors and natural transformations. At this level, natural transformations not only compare functors but also look inside the first level objects (system components) thus 'closing' the structure and establishing 'the universal links' between items as an integration of both first and second level links between items. Note, however, that in general categories the objects have no 'inside', though they may do so for example in the case of 'concrete' categories.

From the point of view of mathematical modelling, the mathematical theory of categories models the dynamical nature of reality by representing temporal changes through either *variable* categories or through *toposes.* According to Mac Lane and Moerdijk (2004) certain variable categories can also be generated as a topos. For example, the category of sets can be considered as a topos whose only generator is just a single point. A variable category of varying sets might thus have just a generator set. However, a qualitative distinction *does exist* between organisms– considered as complex systems– and 'simple', inanimate dynamical systems, in terms of the modelling process and the type of predictive mathematical models or representations that they can have (Rosen,1987, and also, previously, in Baianu, 1968 through 1987). A relevant example of applications to the natural sciences, e.g., neurosciences, would be the higher-dimensional algebra representation of processes of cognitive processes of still more, linked sub-processes (Brown, 2004). Additional examples of the usefulness of such a categorical constructive approach to generating higher-level mathematical structures would be that of supergroups of groups of items, 2-groupoids, or double groupoids of items.

3.2.1. *Symmetry, Commutativity and Abelian Structures.* The hierarchy constructed above, up to level 3, can be further extended to higher, n-levels, always in a consistent, natural manner, that is using commutative diagrams. Let us see therefore a few simple examples or specific instances of commutative properties. The type of global, natural hierarchy of items inspired by the mathematical TC-FNT has a kind of *internal symmetry* because at all levels, the link compositions are *natural*, that is, if $f : x \longrightarrow y$ and $g : y \longrightarrow z \Longrightarrow h : x \longrightarrow z$, then the composition of morphism g with f is given by another unique morphism $h = g \circ f$. This general property involving the equality of such link composition chains or diagrams comprising any number of sequential links between the same beginning and ending

objects is called *commutativity* (see for example Samuel and Zarisky, 1957), and is often expressed as a *naturality condition for diagrams.* This key mathematical property also includes the mirror-like symmetry $x \star y = y \star x$; when x and y are operators and the symbol '$\star$' represents the operator multiplication. Then, the equality of $x \star y$ with $y \star x$ defines the statement that "the x and y operators *commute*"; in physical terms, this translates into a sharing of the same set of eigenvalues by the two commuting operators, thus leading to 'equivalent' numerical results i.e., up to a multiplication constant); furthermore, the observations X and Y corresponding, respectively, to these two operators would yield the same result if X is performed before Y in time, or if Y is performed first followed by X. This property, when present, is very convenient for both mathematical and physical applications (such as those encountered in quantum mechanics). However, not all quantum operators 'commute', and not all categorical diagrams or mathematical structures are, or need be, commutative. *Non-commutativity* may therefore appear as a result of 'breaking' the 'internal symmetry' represented by commutativity. As a physical analogy, this might be considered a kind of *'symmetry breaking'* which is thought to be responsible for our expanding Universe and CPT violation, as well as many other physical phenomena such as phase transitions and superconductivity (Weinberg, 2003).

On the one hand, when commutativity is global in a structure, as in an Abelian (or commutative) group, commutative groupoid, commutative ring, etc., such a structure that is commutative throughout is usually called ***Abelian***. However, in the case of category theory, this concept of Abelian structure has been extended to a special class of categories that have meta-properties formally similar to those of the category of commutative groups, *Ab*-**G**; the necessary and sufficient conditions for such 'Abelianness' of categories other than that of Abelian groups were expressed as three axioms **Ab1** to **Ab3** and their duals (Freyd, 1964; see also the details in Baianu et al 2007b and Brown et al 2007). Among such mathematical structures, *Abelian* categories have particularly interesting applications to rings and modules (Popescu, 1973; Gabriel, 1962) in which commutative diagrams are essential. Commutative diagrams are also being widely used in Algebraic Topology (Brown, 2005; May, 1999). As one can see from both the earlier and more recent literature, Abelian categories have been studied in great detail, even though their study is far from complete.

On the other hand, the more general case is the *non-commutative* one. Several intriguing, 'non-commutative' or non-Abelian, examples are provided by certain *asymmetric* drawings by Escher, such as his perpetuum water mill, or his 3D-evading, illusory castle with monks 'climbing' from one level to the next–at 'same-height' (that might be considered as a hint to paradoxes caused by the imposition of only one level of reality, similar to Abbott's flatland).

3.2.2. *Abelian Meta-Theorems.* Freyd (1964) has an interesting section on **meta**-theorems in his book on Abelian categories. In essence all propositions, or mathematical truth statements of a specific mathematical form "***p***" that are valid for the category of Abelian groups are also valid in any extended Abelian category defined by axioms Ab1 to Ab3 and their duals. Other types of meta-theorems are also possible for super-categories of categories, and of course such meta-theorems are not restricted to Abelian structures.

3.3. **Non-Abelian Theories and Spacetimes Ontology.** Any comprehensive Categorical Ontology theory is *a fortiori non-Abelian*, and thus recursively non-computable, on account of both the quantum level (which is generally accepted as being non-commutative), and the top ontological level of the human mind– which also operates in a non-commutative manner, albeit with a different, *multi-valued* logic than Quantum Logic. To sum it up, the operating/operational logics at both the top and the fundamental levels are *non-commutative* (the 'invisible' actor (s) who– behind the visible scene– make(s) both the action and play possible!). At the fundamental level, spacetime events occur according to a quantum logic (QL), or *Q-logic*, whereas at the top level of human consciousness, a different, non-commutative Higher Dimensional Logic Algebra prevails akin to the many-valued (Łukasiewicz - Moisil, or LM) logics of genetic networks which were shown previously to exhibit non-linear, and also non-commutative/non-computable, biodynamics (Baianu, 1977, 1987; Baianu, Brown, Georgescu and Glazebrook, 2006). Our viewpoint is that models constructed from category theory and higher dimensional algebra have potential applications towards creating a higher science of analogies which, in a descriptive sense, is capable of mapping imaginative subjectivity beyond conventional relations of complex systems. Of these, one may strongly consider a *generalized chronoidal–topos* notion that transcends the concepts of spatial–temporal geometry by incorporating *non-commutative multi–valued logic*. Current trends in the fundamentally new areas of quantum–gravity theories appear to endorse taking such a direction. We aim further to discuss some prerequisite algebraic–topological and categorical ontology tools for this endeavor, again relegating all rigorous mathematical definitions to the Brown, Glazebrook and Baianu (2007). It is interesting that Abelian categorical ontology (ACO) is also acquiring several new meanings and practical usefulness in the recent literature related to computer-aided (ontic/ontologic) classification, as in the case of: neural network categorical ontology (Baianu, 1972; Ehresmann and Vanbremeersch, 1987, Healy, 2006), Genetic Ontology, Biological Ontology, Environmental representations by categories and functors (Levich and Solovy'ov., 1999), or ultra-complex societies.

An example of a non-commutative structure relevant to Quantum Theory is that of the *Clifford algebra* of quantum observable operators (Dirac, 1962; see also Plymen and Robinson, 1994). Yet another- more recent and popular- example in the same QT context is that of C^*–algebras of (quantum) Hilbert spaces. Furthermore, the microscopic, or quantum, 'first' level of physical reality does *not* appear to be subject to the categorical naturality conditions of Abelian TC-FNT– the 'standard' mathematical theory of categories (functors and natural transformations). It would seem therefore that the commutative hierarchy discussed above is not sufficient for the purpose of a General, Categorical Ontology which considers all items, at all levels of reality, including those on the 'first', quantum level, which is non–commutative. On the other hand, the mathematical, Non-Abelian Algebraic Topology (Brown, Higgins and Sivera, 2007), the Non-Abelian Quantum Algebraic Topology (NA-QAT; Baianu et al., 2005), and the physical, Non-Abelian Gauge theories (NAGT) may provide the ingredients for a proper foundation for Non-Abelian, hierarchical multi-level theories of a super-complex system dynamics in a General Categorical Ontology (GCO). Furthermore, it was recently pointed out (Baianu *et al.*, 2005, 2006) that the current and future development of both NA-QAT and of a quantum-based Complex Systems Biology, *a fortiori*, involve *non-commutative*, many-valued logics of quantum events, such as a modified Łukasiewicz–Moisil (LMQ) logic algebra (Baianu, Brown, Georgescu and Glazebrook, 2006), complete with a fully-developed, novel probability measure theory grounded in the LM-logic algebra (Georgescu, 2006b). The latter paves the way to a new projection operator theory founded upon the *non-commutative quantum logic of events*, or dynamic processes, thus opening the possibility of a complete, *Non–Abelian Quantum theory*. Furthermore, such recent developments point towards a paradigm shift in Categorical Ontology and to its extension to more general, *Non-Abelian theories*, well beyond the bounds of commutative structures/spaces and also free from the *logical* restrictions and limitations imposed by set theory.

3.4. **Duality Concepts in Philosophy and Category Theory.** Duality and dual concepts are, and have been for a long time, the subject of philosophical investigations, including ontological ones. From the ancient Yin and Yang to the more modern dualistic approaches to philosophy by Descartes or Hegel, dual concepts still hold a special attraction for the philosopher and mathematician who is concerned with then *unity* of nature and systems, be they natural or abstract/mathematical. Indeed, it would seem that *duality and adjointness* are at the heart of trends towards unity in mathematics (Lawvere, 1966; Ehresmann, 1966; SEP, 2006 and references cited therein). Like the two sides of a coin, both different/distinct/apposite and necessary, dual concepts are, according to Hegel, the very essence of dynamics and dialectics. In categories, duality is practically and very simply obtained by 'reversing the arrows' (May, 1999). When all arrows are invertible in a category one has the natural structure of a *groupoid*, a structure that is fundamental in Topology (Brown, 2006). Interestingly, most symmetric structures– as well as more generally– Abelian ones, are *self-dual*; likewise, the quantum operators representing observables are *self-adjoint*, and the Clifford algebra of quantum algebra is self-dual. The subject of duality deserves a very detailed and thorough consideration which is beyond the scope of this essay; such considerations may very well lead to the fundamental structures of spacetime itself since space and time seem to be dual concepts joined together by the relativity of reference systems, and also tied up with the subtle nature of quantum gravity.

3.5. **Systems Classification in Ontology: Simple/Complex–Chaotic, Super–Complex and Ultra–Complex Systems viewed as Three Distinct Levels of Reality: Dynamic Analogy and Homology.** We introduce here a few basic definition of a general, dynamical system that may facilitate further developments of the theory of levels in categorical ontology. No claim is here made however to either universality or mathematical rigour.

Defining Dynamic Systems as Stable Spacetime Structures with Boundaries.

As defined in Baianu and Poli (2008), a system is a dynamical (whole) entity able to maintain its working conditions; the system definition is here spelt out in detail by the following, general definition, **D1**.

D1. A simple system is in general a bounded, but not necessarily closed, entity– here represented as a category of stable, interacting components with inputs and outputs from the system's environment, or as a supercategory for a complex system consisting of subsystems, or components, with internal boundaries among such subsystems.

As proposed by Baianu and Poli (2008) in order to define a system one therefore needs specify the following data: (1) components or subsystems, (2) mutual interactions or links; (3) a separation of the selected system by some boundary which distinguishes the system from its environment, without necessarily 'closing' the system to material exchange with its environment; (4) the specification of the system's environment; (5a) the specification of the system's categorical structure and dynamics; (5b) a supercategory will be required only when either the components or subsystems need be themselves considered as represented by a category , i.e. the system is in fact a super-system of (sub)systems, as it is the case of all emergent super-complex systems or organisms.

As discussed by Baianu and Poli (2008), "the most general and fundamental property of a system is the *inter-dependence* of parts/components/sub-systems or variables." ; *inter-dependence* is the presence of a certain organizational order in the relationship among the components or subsystems which make up the system. It can be shown that such organizational order must either result in a stable attractor or else it should occupy a stable spacetime

domain, which is generally expressed in *closed* systems by the concept of equilibrium. On the other hand, in non-equilibrium, open systems, one cannot have a static but only a *dynamic self-maintenance* in a 'state-space region' of the open system – which cannot degenerate to either an equilibrium state or a single attractor spacetime region. Thus, non-equilibrium, open systems that are capable of self-maintenance (seen as a form of autopoiesis) will also be generic, or structurally-stable: their arbitrary, small perturbation from a homeostatic maintenance regime does not result either in completely chaotic dynamics with a single attractor or the loss of their stability. It may however involve an ordered process of changes - a process that follows a determinate pattern rather than random variation relative to the starting point. Systems are usually conceived as 'objects', or things, rather than processes even though at the core of their definition there are dynamic laws of evolution. Spencer (1898) championed such evolutionary ideas/laws/principles not only in the biosphere but also in psychology and human societies. Furthermore, the usual meaning of 'dynamic systems' is associated with their treatments by a 'system' (array) of differential equations (either exact, ordinary or partial); note also that the latter case also includes 'complex' chaotic systems whose solutions cannot be obtained by recursive computation, for example with a digital computer or supercomputer.

Selective Boundaries and Homeostasis. Varying Boundaries vs Horizons.

Boundaries are especially relevant to *closed* systems, although they also exist in many open systems. According to Poli (2008): "they serve to distinguish what is internal to the system from what is external to it", thus defining the fixed, overall structural topology of a closed system. By virtue of possessing boundaries, "a whole (entity) is something on the basis of which there is an interior and an exterior...which enables a difference to be established between the whole closed system and environment." (cf. Baianu and Poli, 2008, in this volume). As proposed by Baianu and Poli (2008), an essential feature of boundaries in open systems is that they can be crossed by matter. The boundaries of closed systems, however, cannot be crossed by molecules or larger particles. On the contrary, a horizon is something that one cannot reach. In other words, a horizon is not a boundary. This difference between horizon and boundary appears to be useful in distinguishing between systems and their environment.

One notes however that a boundary, or boundaries, may change or be quite selective/directional–in the sense of dynamic fluxes crossing such boundaries–if the system is *open* and grows/develops as in the case of an organism, which will be thus characterized by a *variable* topology that may also depend on the environment, and is thus *context-dependent* as well. Perhaps the simplest example of a system that changes from *closed to open*, and thus has a *variable topology*, is that of a pipe equipped with a functional valve that allows flow in only one direction. On the other hand, a semi-permeable membrane such as a cellophane, thin-walled 'closed' tube– that allows water and small molecule fluxes to go through but blocks the transport of large molecules such as polymers through its pores– is *selective* and may be considered as a primitive/'simple' example of an open, selective system. Organisms, in general, are *open systems with variable topology* that incorporate both the valve and the selectively permeable membrane boundaries –albeit much more sophisticated and dynamic than the simple/fixed topology cellophane membrane–in order to maintain their stability and also control their internal structural order, or low microscopic entropy. The formal definition of this important concept of *'variable topology'* was introduced in our recent paper (Baianu et al 2007a) in the context of the spacetime evolution of organisms, populations and species. Interestingly, for many multi-cellular organisms, including man, the overall morphological symmetry (but not the internal organizational topology) is retained from the beginning of ontogenetic development is externally bilateral–just one plane of mirror symmetry– from *Planaria* to humans. The presence of the head-to-tail asymmetry introduces increasingly marked differences among the various areas of the head, middle, or tail regions as the organism develops. There is however in man– as in other mammals– an internal bilateral asymmetry (e.g., only one heart on the left side), as well as a front to back, both external and internal anatomical asymmetry. In the case of the brain, however, only humans seem to have a significant bilateral, internal asymmetry between the two brain hemispheres that interestingly relates to the speech-related 'centers' (located in the majority of humans in the left brain hemisphere).

The multiplicity of boundaries, and the dynamics that derive from it, generate interesting phenomena. Boundaries tend to reinforce each other, as in the case of dissipative structures formed through coupled chemical, chaotic reactions. According to Poli (2008), *"this somewhat astonishing regularity of nature has not been sufficiently emphasized in perception philosophy."*

3.5.1. *Simple and Super–Complex Dynamics: Closed vs. Open Systems.* In an early report (Baianu and Marinescu, 1968), the possibility of formulating a Super–Categorical Unitary Theory of Systems (i.e., both simple and complex, etc.) was pointed out both in terms of organizational structure and dynamics. Furthermore, it was proposed that the formulation of any model or 'simulation' of a complex system– such as living organism or a society–involves generating a first–stage *logical model* (not-necessarily Boolean!), followed by a *mathematical* one, *complete with structure* (Baianu, 1970). Then, it was pointed out that such a modelling process involves a diagram containing the complex system, (**CS**) and its dynamics, a corresponding, initial logical model, **L**, *'encoding'* the essential dynamic and/or structural properties of **CS**, and a detailed, structured mathematical model (**M**); this initial modelling

diagram may or may not be commutative, and the modelling can be iterated through modifications of $\boldsymbol{L}$, and/or $\mathbf{M}$, until an acceptable agreement is achieved between the behaviour of the model and that of the natural, complex system (Baianu and Marinescu, 1968; Comoroshan and Baianu, 1969). Such an *iterative modelling* process may ultimately 'converge' to appropriate models of the complex system, and perhaps a best possible model could be attained as the categorical colimit of the directed family of diagrams generated through such a modelling process. The possible models $\mathbf{L}$, or especially $\mathbf{M}$, were not considered to be necessarily either numerical or recursively computable (e.g., with an algorithm or software program) by a digital computer (Baianu, 1971b, 1986-87). The mathematician John von Neumann regarded 'complexity' as a measurable property of natural systems below the threshold of which systems behave 'simply', but above which they evolve, reproduce, self–organize, etc. It was claimed that any 'natural' system fits this profile. But the classical assumption that natural systems are simple, or 'mechanistic', is too restrictive since 'simple' is applicable only to machines, closed physicochemical systems, computers, or any system that is recursively computable. Rosen (1987) proposed a major refinement of these ideas about complexity by a more exact classification between 'simple' and 'complex'. Simple systems can be characterized through representations which admit maximal models, and can be therefore re–assimilated via a hierarchy of informational levels. Besides, the duality between dynamical systems and states is also a characteristic of such simple dynamical systems. Complex systems do not admit any maximal model. On the other hand, an *ultra-complex* system– as applied to psychological–sociological structures– can be described in terms of *variable categories* or structures, and thus cannot be reasonably represented by a fixed state space for its entire lifespan. Simulations by limiting dynamical approximations lead to increasing system 'errors'. Just as for simple systems, both *super–complex* and *ultra-complex* systems admit their own orders of causation, but the latter two types are different from the first–by inclusion rather than exclusion– of the mechanisms that control simple dynamical systems.

3.5.2. *Commutative vs. Non-commutative Dynamic Modelling Diagrams.* Interestingly, Rosen (1987) also showed that complex dynamical systems, such as biological organisms, cannot be adequately modelled through a *commutative* modelling diagram– in the sense of digital computer simulation–whereas the simple ('physical'/ engineering) dynamical systems can be thus numerically simulated. Furthermore, his modelling commutative diagram for a *simple dynamical system* included both the 'encoding' of the 'real' system $\mathbf{N}$ in ($\mathbf{M}$) as well as the 'decoding' of ($\mathbf{M}$) back into $\mathbf{N}$:

$$\begin{tikzcd}
[SYSTEM] \arrow[r, "\textbf{Encoding...}\hookrightarrow"] \arrow[d, "\delta"'] & LOGICS \oplus MATHS. \arrow[d, "\aleph_M"] \\
SYSTEM & {[MATHS.\square MODEL]} \arrow[l, "\textbf{Decoding} \hookleftarrow ..."]
\end{tikzcd}$$

where δ is the real system dynamics and $\aleph$ is an algorithm implementing the numerical computation of the mathematical model ($\mathbf{M}$) on a digital computer. Firstly, one notes the ominous absence of the *Logical Model*, $\boldsymbol{L}$, from Rosen's diagram published in 1987. Secondly, one also notes the obvious presence of logical arguments and indeed (*non-Boolean*) 'schemes' related to the entailment of organismic models, such as **MR**-systems, in the more recent books that were published last by Robert Rosen (1994, 2001, 2004). This will be further discussed in Section 4, with the full mathematical details provided in the paper by Brown, Glazebrook and Baianu (2007). Furthermore, Elsasser (1980) pointed out a fundamental, logical difference between physical systems and biosystems or organisms: whereas the former are readily represented by *homogeneous* logic classes, living organisms exhibit considerable variability and can only be represented by *heterogeneous* logic classes. One can readily represent homogeneous logic classes or endow them with 'uniform' mathematical structures, but heterogeneous ones are far more elusive and may admit a multiplicity of mathematical representations or possess variable structure. This logical criterion may thus be useful for further distinguishing simple systems from highly complex systems.

The importance of *Logic Algebras*, and indeed of *Categories of Logic Algebras*, is rarely discussed in modern Ontology even though categorical formulations of specific Ontology domains such as Biological Ontology and Neural Network Ontology are being extensively developed. For a recent review of such categories of logic algebras the reader is referred to the concise presentation by Georgescu (2006); their relevance to network biodynamics was also recently assessed (Baianu, 2004, Baianu and Prisecaru, 2005; Baianu et al, 2006).

Super-complex systems, such as those supporting neurophysiological activities, are explained only in terms of non–linear, rather than linear causality. In some way then, these systems are not normally considered as part of either traditional physics or the complex 'chaotic' systems physics that are known to be fully deterministic. However, super-complex (biological) systems have the potential to manifest novel and counter–intuitive behavior such as in the manifestation of 'emergence', development/morphogenesis and biological evolution. The precise meaning of supercomplex systems is formally defined here in Section 3.3.

3.5.3. *Comparing Systems: Similarity Relations between Analogous or Adjoint Systems. Diagrams Linking Super– and Ultra– Complex/Meta–Levels. Classification as a Dynamic Analogy, Categorical Adjointness or Functional Homology.* Categorical comparisons of different types of systems in diagrams provide useful means for their classification and understanding the relations between them. From a global viewpoint, comparing categories of such different systems does reveal useful analogies, or similarities, between systems and also their universal properties. According to Rashevsky (1969), general relations between sets of biological organisms can be compared with those between societies, thus leading to more general principles pertaining to both. This can be considered as a further, practically useful elaboration of Spencer's philosophical principle ideas in biology and sociology. When viewed from a formal perspective of Poli's theory of levels (Baianu and Poli, 2008), the two levels of super– and ultra– complex systems are quite *distinct* in many of their defining properties, and therefore, categorical diagrams that 'mix' such distinct levels *do not commute.*

Considering dynamic similarity, Rosen (1968) introduced the concept of *'analogous'* (classical) dynamical systems in terms of categorical, dynamic isomorphisms between their isomorphic state-spaces that commute with their transition (state) function, or dynamic laws. However, the extension of this concept to either complex or super-complex systems has not yet been investigated, and may be similar in importance to the introduction of the Lorentz-Poincaré group of transformations for reference frames in Relativity theory. On the other hand, one is often looking for *relational invariance* or *similarity in functionality* between different organisms or between different stages of development during ontogeny–the development of an organism from a fertilized egg. In this context, the categorical concept of '*dynamically adjoint systems*' was introduced in relation to the data obtained through nuclear transplant experiments (Baianu and Scripcariu, 1974). Thus, extending the latter concept to super– and ultra– complex systems , one has in general, that two complex or supercomplex systems with 'state spaces' being defined respectively as A and A*, are dynamically adjoint if they can be represented naturally by the following (functorial) diagram:

(3.1)
$$\begin{tikzcd} A \arrow[r, "F"] \arrow[d, "F'"'] & A^* \arrow[d, "G"] \\ A^* \arrow[r, "G'"'] & A \end{tikzcd}$$

with $F \approx F'$ and $G \approx G'$ being isomorphic (that is, $\approx$ representing natural equivalences between adjoint functors of the same kind, either left or right), and as above in diagram (2.5), the two diagonals are, respectively, the state-space transition functions $\Delta : A \rightarrow A$ and $\Delta^* : A^* \rightarrow A^*$ of the two adjoint dynamical systems. (It would also be interesting to investigate dynamic adjointness in the context of quantum dynamical systems and quantum automata, as defined in Baianu, 1971a).

A *left-adjoint* functor, such as the functor F in the above commutative diagram between categories representing state spaces of equivalent cell nuclei *preserves limits*, whereas the *right-adjoint* (or coadjoint) functor, such as G above, *preserves colimits.* (For precise definitions of adjoint functors the reader is referred to Brown, Galzebrook and Baianu, 2007, as well as to Popescu, 1973, Baianu and Scripcariu, 1974, and the initial paper by Kan, 1958).

Thus, dynamical attractors and genericity of states are preserved for differentiating cells up to the blastula stage of organismic development. Subsequent stages of ontogenetic development can be considered only 'weekly adjoint' or partially analogous. Similar dynamic controls may operate for controlling division cycles in the cells of different organisms; therefore, such instances are also good example of the dynamic adjointness relation between cells of different organisms that may be very far apart phylogenetically, even on different 'branches of the tree of life.' A more elaborate dynamic concept of 'homology' between the genomes of different species during evolution was also proposed (Baianu, 1971a), suggesting that an entire phylogenetic series can be characterized by a topologically–rather than biologically–*homologous sequence* of genomes which preserves certain genes encoding *the essential* biological functions. A striking example was recently suggested involving the differentiation of the nervous system in the fruit fly and mice (and perhaps also man) which leads to the formation of the back, middle and front parts of the neural tube. A related, topological generalization of such a dynamic similarity between systems was previously introduced as *topological conjugacy* (Baianu, 1986-1987a; Baianu and Lin, 2004), which replaces recursive, digital simulation with symbolic, topological modelling for both super– and ultra– complex systems (Baianu and Lin., 2004; Baianu, 2004c; Baianu et al., 2004, 2006b). This approach stems logically from the introduction of topological/symbolic computation and topological computers Baianu, 1971b), as well as their natural extensions to quantum nano-automata (Baianu, 2004a), quantum automata and quantum computers (Baianu, 1971a, and 1971b, respectively); the latter may allow us to make a 'quantum leap' in our understanding Life and the higher complexity levels in general. Such is also

the relevance of Quantum Logics and LM-logic algebra to understand the immanent operational logics of the human brain and the associated mind meta–level. Quantum Logics concepts are introduced next that are also relevant to the fundamental, or 'ultimate', concept of spacetime, well-beyond our phenomenal reach, and thus in this specific sense, *transcedental* to our physical experience (perhaps vindicating the need for a Kantian–like *transcedental logic*, but from a quite different standpoint than that originally advanced by Kant in his critique of 'pure' reason; instead of being 'mystical'- as Husserl might have said–the transcedental logic of quantized spacetime is very different from the Boolean logic of digital computers, as it is *quantum*, and thus non–commutative). A *Transcedental Ontology*, whereas with a definite Kantian 'flavor', would not be at all 'mystical' in Husserl's sense, but would rely on 'verifiable' many–valued, non–commutative logics, and thus contrary to Kant's original presupposition, as well as untouchable by Husserl's critique. The fundamental nature of spacetime would be 'provable' and 'verifiable', but only to the extent allowed by Quantum Logics, not by an arbitrary ('mystical') Kantian–transcedental logic or by impossible, direct phenomenal observations at the Planck scale.

3.6. **Irreversibility in Open Systems: Time and Microentropy, Quantum Super-Operators.** A significant part of the scientific and philosophical work of Ilya Prigogine (see e.g. Prigogine, 1980) has been devoted to the dynamical meaning of phenomenal/physical *irreversibility* expressed in terms of the second law of thermodynamics. For systems with strong enough instability of motion the concept of phase space trajectories is no longer meaningful and the dynamical description has to be replaced by the motion of distribution functions on the phase space. The viewpoint is that quantum theory produces a more coherent type of motion than in the classical setting and the quantum effects induce correlations between neighbouring classical trajectories in phase space. Prigogine's idea (1980) is to associate a macroscopic entropy (or Lyapounov function) with a microscopic entropy (quantum) super–operator M . Here the time–parametrized distribution functions ρ_t are regarded as densities in phase space such that the inner product $\langle \rho_t, M\rho_t \rangle$ varies monotonously with t as the functions ρ_t evolve in accordance with Liouville's equation (Prigogine, 1980; Misra et al, 1979). For well defined systems for which the super-operators M exist, a time super-operator T ('age' or 'internal time') can also be introduced. (For the precise details, the reader is referred to Misra et al. 1979). Furthermore, the equations of motion with randomness at the microscopic level then emerge as irreversibility on the macroscopic level. However, unlike the usual quantum operators representing observables, the M super-operators are *non-Hermitian* operators, (i.e., they are not self-adjoint, $M \neq \mathrm{M}^*$). However, there are certain provisions that have to be made in terms of the spectrum of the Hamiltonian H for M to be properly defined: if H has a pure point spectrum, then M does not exist, and likewise, if H has a continuous but bounded spectrum then M cannot exist. Thus, the super-operator M cannot exist in the case of only finitely extended systems containing only a finite number of particles. Furthermore, the super-operator M cannot preserve the class of 'pure states' since it is non-factorizable. The distinction between pure states (represented by vectors in a Hilbert space) and mixed states (represented by density operators) is thus lost in the process of measurement. In other words, the distinction between pure and mixed states is lost in a quantum system for which the algebra of observables can be extended to include a new dynamical variable representing the non-equilibrium entropy. In this way, one may formulate the second law of thermodynamics in terms of M for quantum mechanical systems. Let us mention that the time operator T represents 'internal time' and the usual, 'secondary' time in quantum dynamics is regarded as an average over T. When T reduces to a trivial operator the usual concept of time is recovered $T\rho(x, v, t) = t\rho(x, v, t)$, and thus time in the usual sense is conceived as an average of the individual times as registered by the observer. Given the latter's ability to distinguish between between future and past, a self-consistent scheme may be summarized in the following diagram (Prigogine, 1980):

(3.2)
$$\begin{tikzcd}
\text{Observer} \arrow[r] & \text{Dynamics} \arrow[d] \\
\text{Broken time symmetry} \arrow[u] & \text{Dissipative structures} \arrow[l]
\end{tikzcd}$$

for which 'irreversibility' occurs as the intermediary in the following sequence:

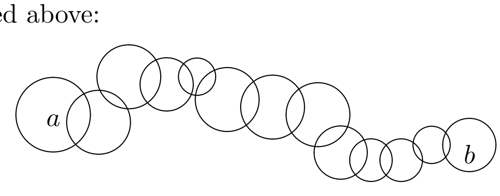
$$\text{Dynamics} \Longrightarrow \text{Irreversibility} \Longrightarrow \text{Dissipative structures}$$

(Note however that certain quantum theorists, as well as Einstein, regarded the irreversibility of time as an 'illusion' caused by statistical averaging. Others– operating with minimal representations in quantum logic for finite quantum systems– go further still by denying that there is any need for real time to appear in the formulation of quantum theory.)

The importance of the above diagram will become fully apparent in the context of Section 4 , where we discuss living organisms in terms of *open* systems that by definition are irreversible, and also have highly complex (generic) dynamics supported by *dissipative* structures which may have come into existence through *'symmetry breaking'* , as explained in further detail by Baianu and Poli, 2008, in this volume, and also briefly in the next subsection. This diagram sketches four major pieces from the puzzle of the emergence/origin of life on earth, without however coming very close to completing this puzzle; thus, Prigogine's subtle concepts of microscopic time and micro–entropy super–operators may allow us to understand how life originated on earth several billion years ago, and also how organisms function and survive today. They also provide a partial answer to subtle quantum genetics and fundamental evolutionary dynamics questions asked by Schrödinger– one of the great founders of quantum 'wave mechanics'– in his widely read book "What is Life?" Other key answers to the latter's question were recently provided by Robert Rosen (2000) in his popular book "Essays on Life Itself.", unfortunately without any possibility of continuation or of reaching soon the 'ultimate' or complete answer. Schrödinger's suggestion that living organisms "feed on 'negative entropy'...," was at least in part formalized by Prigogine's super-operators, such as M. This theory is in great need of further developments that he could not complete during his lifespan; such developments may also include several of Rosen 's (2000) suggestions and will apparently require a categorical and Higher Dimensional Algebraic, non–Abelian theory of irreversible thermodynamics, as well as a quantum–mechanical statistics of open systems that are capable of autopoiesis, e.g. living organisms.

3.6.1. *Iterates of Local Procedures using Groupoid Structures.* Often we will look for a modelling of levels regarded as highly complex systems that can be described in terms of specific categorical structures and natural transformations of functors which compare modelling diagrams or categories. A special subclass of categories is that of *groupoids*–small categories with all morphisms *invertible* (Brown 2006, Weinstein 1996). These are essential as descriptive models for the reciprocity (i.e., *morphism invertibility, or isomorphism*) in the relay of signalling that occurs in various classes of genetic, neural and bionetworks, besides providing descriptive mechanisms for *local–to–global* properties within the latter, the collection of objects of which can comprise various genera of organismic sets. Groupoid actions and certain convolution algebras of groupoids (cf. Connes, 1994) were suggested to be the main carriers of *non–commutative processes.* Many types of cell systems such as those representative of neural networks or physiological locomotion, can be described in terms of equivalence classes of cells, links and inputs, etc. leading to the notion of a system's *symmetry groupoid* the breaking of which can induce a transition from one state to another (Golubitsky and Stewart 2006). This notion of classification involves equivalence relations, but the groupoid point of view extends this notion not only to say that two elements are equivalent but also to label the proofs that they are equivalent. Such an approach features in an information-based theory of interactive cognitive modules cast within the Baars global neuronal workspace (Wallace, 2005). The theories of Shannon (information) and Dretske (communication) are combined in an immunology/language and network analysis/groupoid setting to describe a fundamental homology with the thermodynamic principles as derived from statistical physics. The thread of ideas may be exemplified by such cognitive disorders as *inattentional blindness* and *psycho-social stress* (Wallace, 2007) resulting from such factors as information distortion/overload, socio-cultural pressure, and as represented by the manifestation of network transition phases (often attributed to an *induced symmetry breaking* within the network in question). Such cognitive disorders are considered as having their analogues at the levels of culturally embedded/institutional, higher level multi-tasking where such ailments can result in a demise or total failure of the constituent operative systems. The latter include the general areas of public health administration, (disease prevention, therapeutic practice, etc.), environmental/ecological management, to name a few.

The notion of *holonomy* occurs in many situations, both in physics and differential geometry. Non–trivial holonomy occurs when an iteration of local procedures which returns to the starting point can yield a change of phase, or of other more general values. Charles Ehresmann realized the notion of *local procedure* formalised by the notion of *local smooth admissible section of a smooth groupoid*, and Pradines (1966) generalised this to obtain a *global holonomy Lie groupoid* from a *locally* Lie groupoid: the details were presented in Aof and Brown (1992). This concept of *local procedure* may be applicable to the evolution of super-complex systems/organisms for which there are apparently "missing links"–ancestors whose fossils cannot be found; when such links are genuinely missing, the evolution process can be viewed as maintaining an evolutionary trend not by virtue of analytical continuity, from point to point, but through overlapping regions from networks of genes and their expressed phenotype clusters. This idea of a local procedure applied to speciation is illustrated below, with the intermediate circles representing such possible missing links, without the need to appeal to 'catastrophes'. In this speciation example, the following picture illustrates a chain of local procedures (COLP) leading from species a to species b *via* intermediates that are not 'continuous' in the analytical sense discussed above:



One would like to be able to define such a chain, and equivalences of such chains, without resource to the notion of 'path' between points. The claim is that a candidate for this lies in the constructions of Charles Ehresmann and Jean Pradines for the *holonomy groupoid*. The globalization of structure can be thus encoded in terms of the *holonomy groupoid* which for any groupoid–related system encodes the notion of the subsequent *phase transition* (and its amplitude) of the latter phase towards a new phase (Aof and Brown, 1992). One question is whether a COLP is either a fact or a description. Things evolve and change in time. We think usually of this change as a real number modelling of time. But it may be easier to see what is happening as a COLP, since each moment of time has an environment, which is carried along as things evolve. The Aof-Brown paper, based on certain ideas of Charles Ehresmann and Jean Pradines, shows that such ideas have a mathematical reality, and that some forms of holonomy are nicely described in this framework of the globalisation theorem for a locally Lie groupoid. The generalization of the manifold/atlas structure (Brown, 2006) is that of the *groupoid atlas* (Bak, 2006; and Brown, Glazebrook and Baianu, 2007), which is relevant in 'concurrent' and 'multi–agent systems' (Porter, 2002); however, concurrent and multi-agent systems are distinct, though they may be somehow related to the atlas structure. Concurrency itself is a theory about many processes occurring at the same time, or, equivalently, about processes taking place in multiple times. Since time has a direction, *multiple times* have a 'multiple direction', hence the *directed spaces*. This leads to a novel descriptive and computational technique for charting informational flow and management in terms of *directed spaces, dimaps and dihomotopies* (see e.g. Goubault, 2003). These may provide alternative approaches to *'iterates of local procedures'* along with key concepts such as the notion of 'scheduling of paths' with respect to a cover that can be used as a globalization technique, for instance, to recover the Hurewicz continuous fibration theorem (Hurewicz, 1955) as in Dyer and Eilenberg (1988).

Ontological levels themselves will entail '*processes* of processes' for which HDA seeks to provide the general theories of transport along n–paths and subsequent n–holonomy (cf. Brown and İçen, 2003 for the two-dimensional case), thus leading to a globalizaton of the dynamics of local networks of organisms across which multiple morphisms interact, and which are multiply–observable. This representation, unless further specified, may not be able, however, to distinguish between levels and multiple processes occurring on the same level.

3.6.2. *Local–to–Global (LG) Construction Principles consistent with Quantum 'Axiomatics'.* A novel approach to QST construction in Algebraic/Axiomatic QFT involves the use of generalized fundamental theorems of algebraic topology from specialized, 'globally well-behaved' topological spaces, to arbitrary ones (Baianu et al, 2007c). In this category, are the generalized, *Higher Homotopy van Kampen theorems (HHvKT)* of Algebraic Topology with novel and unique non-Abelian applications. Such theorems greatly aid the calculation of higher homotopy of topological spaces. R. Brown and coworkers (1999, 2004a,b,c) generalized the van Kampen theorem, at first to fundamental groupoids on a set of base points (Brown,1967), and then, to higher dimensional algebras involving, for example, homotopy double groupoids and 2-categories (Brown, 2004a). The more sensitive *algebraic invariant* of topological spaces seems to be, however, captured only by *cohomology* theory through an algebraic *ring* structure that is not accessible either in homology theory, or in the existing homotopy theory. Thus, two arbitrary topological spaces that have isomorphic homology groups may not have isomorphic cohomological ring structures, and may also not be homeomorphic, even if they are of the same homotopy type. Furthermore, several *non-Abelian* results in algebraic topology could only be derived from the Generalized van Kampen Theorem (cf. Brown, 2004a), so that one may find links of such results to the expected *'non-commutative* geometrical' structure of quantized spacetime (Connes, 1994). In this context, the important algebraic–topological concept of a *Fundamental Homotopy Groupoid (FHG) is applied to a Quantum Topological Space (QTS)* as a "partial classifier" of the *invariant* topological properties of quantum spaces of *any* dimension; quantum topological spaces are then linked together in a *crossed complex over a quantum groupoid* (Baianu, Brown and Glazebrook, 2006), thus suggesting the construction of global topological structures from local ones with well-defined quantum homotopy groupoids. The latter theme is then further pursued through defining locally topological groupoids that can be globally characterized by applying the Globalization Theorem, which involves the *unique* construction of the Holonomy Groupoid. We are considering in a separate publication(Baianu et al 2007c) how such concepts might be applied in the context of Algebraic or Axiomatic Quantum Field Theory (AQFT) to provide a local-to-global construction of Quantum SpaceTimes which would still be valid in the presence of intense gravitational fields without generating singularities as in GR. The result of such a construction is a *Quantum Holonomy Groupoid*, (QHG) which is unique up to an isomorphism.

3.7. **Dynamic Emergence and Entailment of the Higher Complexity Levels.** We shall be considering the question of how biological, psychological and social functions are entailed through *emergent* processes of increasing complexity in higher-dimensional spacetime structures that are essential to Life, Evolution of Species and Human Consciousness. Such emergent processes in the upper three levels of reality considered by Poli (2006b) have corresponding, defining levels of increasing dynamic complexity from biological to psychological and, finally, to the social level. It is therefore important to distinguish between the *emergent* processes of higher complexity and the

underlying, component physicochemical processes. Chaotic dynamics are *not*, however, *emergent* systems because their existence does not require aggregation, or the presence of a level higher than molecular. We are here defending the claim that all 'true' dynamic complexity of higher order is *irreducible* to the dynamics of sub-processes–usually corresponding to a lower level of reality–and it is therefore a truly *emergent*, real phenomenon. In other words, **no emergence** $\Rightarrow$ **no complexity** higher than that of physicochemical systems with chaos, whereas reductionists now attempt to reduce everything, from life to societies and ecology, to systems with just chaotic behaviour. The detailed nature of the higher level emergence will be further developed and treated in a more formal/precise manner in the following sections.

As explained above, there is an ongoing ambiguity and also inconsistency in the current use of the term 'complex', as in 'complex dynamics and dynamical systems'– which is employed by chaotic physics reports and textbooks with a very different meaning from the one customarily employed in Relational Biology (Rosen,1987; and also earlier, more general definitions proposed by Baianu (1968 through 1987). We propose, however, to retain the term 'complexity'–in accord with the use adopted for the field of physicochemical chaotic dynamics demanded by modern physicists and chemists. Then, in order to avoid the recurring confusion that would occur between inanimate, chaotic or robotic, systems that are 'complex' and living organisms which are at a distinctly higher level of dynamic complexity, we propose to define the latter, higher complexity level of *biosystems* as *'supercomplex'*. Thus, we suggest that the *biological* complex systems–whose dynamics is quite distinct from that of *physical* 'complex systems'– should be called *'supercomplex'* (Baianu and Poli, 2007). (Elsasser also claimed that living organisms are 'extremely complex', as discussed in a recent report (Baianu, 2006)). For example, a collection of parts could be assembled through a categorical *colimit*, as it will be shown in a subsequent section (8). Note also that a categorical colimit is defined not just by its parts but also by the morphisms between the objects, which conforms with the naive view that an engine, say, is not just a collection of parts, but depends crucially on how they are put together, if it is to work!

Interestingly, the term 'super-complex' is already in use in the computer industry for high performance digital computer systems designed with a high-degree of parallel processing, whose level of complexity is, however, much lower than that of physicochemical chaotic systems that are called 'complex' by physicists. On the other hand, in the fields of structural and molecular biology, the term 'super-complex' recently designates certain very large super-aggregates of biopolymers that are functional within a cell. Thus, our proposed use of the term $\langle$ *super-complex* $\rangle$ is for the higher level of organization–that of the *whole, functional organism*, not for the first (physicochemical) level of reality–no matter how complicated, 'chaotic' or intricate it is at the molecular/atomic/quantum level. Therefore, in our proposed terminology, *the level of super-complex dynamics is the first emergent level*–which does correspond to the first emergent level of reality in the ontological theory of levels recently proposed by Poli (2006a,b). A more precise formulation and, indeed, resolution of such emergent complexity issues will be presented in the following sections. Our approach from the perspectives of spacetime ontology and dynamic complexity thus requires a reconsideration of the question how new levels of dynamic complexity arise at both the biological and psychological levels. Furthermore, the close interdependence/two-way relations of the psychological and social levels of reality (Poli, 2006a) do require a consideration of the correlations between the dynamic complexities of human consciousness and human society. The *emergence* of one is ultimately determined by the other, in what might be expressed as *iterated feedback and/or feedforward loops*, though not restricted to the engineering meaning which is usually implied by these terms. Thus, *feedforward* loops should be understood here in the sense of *anticipatory* processes, that can, for example, lead in the future to the improvement of social interactions through deliberate, conscious human planning–or even more–to the prevention of the human, and other species, extinction. Further *inter-relations* among the different ontological levels of system complexity are discussed in Baianu and Poli (2007).

3.7.1. *Super-Complex System Dynamics in Living Organisms: Genericity, Multi-Stability and Variable State Spaces.* The important claim is here defended that above the level of 'complex systems with chaos' there is still present a higher, super-complexity level of living organisms –which are neither machines/simple dynamical systems nor are they mere 'chaotically'– behaving systems, in the sense usually employed by the physical theory of 'chaotic' dynamics. These distinct levels, physical/chaotic and biological were represented as distinct objects in the non-commutative diagram of the previous section joined by causal links, running from simple to 'chaotic–complex' (physical) dynamics, then upwards linked to super-complex biodynamics, and still higher to the ultra-complex, meta-level of mental dynamic processes of processes. A further claim is defended that even though the higher levels are linked to– and indeed subsumm, or include – the lower ones in their distinct organization, they are not reducible in a physical or (bio) chemical sense to the lower dynamic level. *In esse*, the distinction between the existence of the higher, super– and ultra– complexity levels and the physical/chemical level of reality can only be made on the basis of their dynamics. Neither Life nor the Mind can be properly conceived as *static*/closed systems, or even as quasi–static structures, without either a time-dependence or associated, material (including energy) and microentropy/gradient-driven flows which are characteristic of *irreversible, open* systems. If the super-complex dynamics stops so does life.

Somewhat similarly, but at a different, higher level of reality, the human mind's ultra–complex existence emerges as a dynamic meta-process of processes, supported also by neural dynamics and life. Artificially separating the mind from the human brain and life in an abstract–'analytical' sense, as in Cartesian Dualism, promotes a static view and an object–based approach that might be relevant, or just partially applicable only to *unconscious* human beings, such as in the case of a severe brain stroke, or even worse, in cases caused by permanent, irrecoverable human brain injuries to a 'living–vegetable' status in grave, major accidents.

Biological organisms are *extremely* complex as recently discussed elsewhere in more detail (Baianu, 2006) in the sense of their required, unique axiomatics (Baianu, 1970), super-complex dynamics (Baianu, 1970 through 2006), new biological/relational principles (Rashevsky, 1968; Baianu and Marinescu, 1968; Baianu, 1970,1971; Rosen, 1970; Baianu et al, 2006) and their *non-computability* with recursive functions, digital computers or Boolean algorithms (Baianu, 1986; Rosen, 1987; Penrose, 2001; Baianu et al, 2006).

In Section 4 we shall examine in further detail how super-complex dynamics emerges in organisms from the *molecular and supra-molecular* levels that recently have already been claimed to exist by several experimental molecular biologists to be 'super-complex'. As shown in previous reports (Baianu, 1973 through 2004; Baianu et al, 2006), multi-cellular organismic development, or ontogeny, can be represented as a directed system or family of dynamic state spaces corresponding to all stages of ontogenetic development of increasing dimensionality. The *colimit* of this *directed system* of ontogenetic stages/dynamic state spaces represents the *mature* stage of the organism (Baianu, 1970 through 2004; Baianu et al. 2006). This emergent process involved in ontogeny leads directly to *variable*, super-complex dynamics and *higher dimensional* state spaces. As an over-simplified, pictorial–but also formalizable–representation, let us consider a living cell as a topological 'cell' or simplex of a CW-complex. Then, as a multi-cellular organism develops a complete simplicial (CW) complex emerges as an over-simplified picture of the whole, mature organism. The higher dimensionality then emerges by considering each cell with its associated, *variable* dynamic state space (Baianu, 1970,1971a,b). As shown in previous reports (Baianu, 1970, 1980), the corresponding variable dynamic structure representing biological relations, functionalities and dynamic transitions is an organismic supercategory, or **OS**. The time-ordered sequence of CW-complexes of increasing dimensionality associated with the development of a multi-cellular organism provides a specific example of a *variable topology.* The 'boundary conditions' or constraints imposed by the environment on the organismic development will then lead to context-dependent variable topologies that are not strictly determined by the genome or developing genetic networks. Although ontogenetic development is usually structurally stable there exist teratogenic conditions or agents that can 'de-stabilize' the developing organism, thus leading to abnormal development. One also has the possibility of abnormal organismic, or brain, development caused by altered genomes, as for example in those cases of autism caused by the fragile-X chromosome syndrome. On the other hand, both single-cell and multi-cellular organisms can be represented in terms of variable dynamic systems, such as generalized **(M,R)-** systems (Baianu, 1973; Baianu and Marinescu, 1974), including dynamic realizations of **(M,R)-** systems (Rosen,1971a,b).

Organisms Represented as Variable Dynamic Systems: Generic States and Dynamic System Genericity.

In actual fact, the super-complexity of the organism itself emerges through the generation of dynamic, variable structures which then also entail variable/flexible functions, homeostasis, autopoiesis, anticipation, and so on. In this context, it is interesting that Wiener (1950,1989) proposed the simulation of living organisms by variable machines/automata that did not exist in his time. The latter were subsequently formalized independently in two related reports (Baianu, 1971a,b).

The topologist René Thom 's metaphorical approach of Catastrophe Theory (1980) to biodynamics, provides some insights of *structural stability* and biodynamics *via* 'generic' states that when perturbed lead to other similarly stable states. When viewed from a categorical standpoint, organismic dynamics has been suggested to be characterized not only by homeostatic processes and steady state, but also by *multi-stability* (Baianu, 1970). The latter concept is clearly equivalent from a dynamic/topological standpoint to super-complex system genericity, and the presence of *multiple dynamic attractors* (Baianu, 1971) which were categorically represented as *commutative super–pushouts* (Baianu, 1970). The presence of generic states and regions in super-complex system dynamics is thus linked to the emergence of complexity through both structural stability and the *open* system attribute of any living organism that enable its persistence in time, in an accommodating niche, suitable for its competitive survival.

3.7.2. *Anticipation in Super– and Ultra– complex Systems. Feedbacks and Feedforward. Autopoiesis.* Rosen (1985, 1987) characterized a change of state as governed by a predicted future state of the organism and/or in respect of its environment. These factors appear separate from the idea of simple systems since future influence (*via* inputs, etc.) are not seen as compatible with causality. Any effort to monitor a complex system through a predictive dynamic model results in a growing discrepancy between the actual function of the system and its predicative counterpart thus leading to a (global) system failure (Rosen, 1987). Furthermore, *anticipatory behaviour*, considered apart from any non–feedback mechanism, is realized in all levels of biological organization, or the broad–scale *autopoiesis*

of structurally linked systems/processes that continually inter-adjust with their environment over time (Maturana and Varela, 1980). Within a social system the autopoiesis of the various components is a necessary and sufficient condition for realization of the system itself. In this respect, the structure of a society as a particular instance of a social system is determined by the structural framework of the (autopoietic components) and the sum total of collective interactive relations. Consequently, the societal framework is based upon a selection of its component structures in providing a medium in which these components realize their ontogeny. It is just through participation alone that an autopoietic system determines a social system by realizing the relations that are characteristic of that system. Then, the huge number and variety of biological organisms formed through evolution can be understood as a result of the very numerous combinatorial potentialities of *super-complex* systems, as well as the large number of different environmental factors available to organismic evolution.

3.7.3. *Ultra-Complex Systems: The Emergence of the Unique Ultra-Complexity through Co-Evolution of the Human Mind and Society. Ultra- Complex Mental Processes viewed as Meta–Level Dynamics.* Higher still than the organismic level characterized by super-complex dynamics, there emerged perhaps even earlier than 400,000 years ago the *unique, ultra-complex* levels of human mind/consciousness and human society interactions, as it will be further discussed in Section 4. There is now only one species known who is capable of rational, symbolic/abstract and creative thinking as part-and-parcel of consciousness–*Homo sapiens sapiens*– which seems to have descended from a common ancestor with *Homo ergaster*, and separated from the latter some 2.2 million years ago. However, the oldest fossils of *H. sapiens* found so far are just about 400,000 years old.

The following diagram summarizes the relationships/links between such different systems on different ontological levels of increasing complexity from the simple dynamics of physical systems to the ultra-complex, global dynamics of psychological processes, collectively known as 'human consciousness'. With the emergence of the ultra-complex system of the human mind– based on the super-complex human organism– there is always an associated progression towards higher dimensional algebras from the lower dimensions of human neural network dynamics and the simple algebra of physical dynamics, as shown in the following, essentially *non-commutative* categorical ontology diagram. This is similar–but not isomorphic– to the higher dimensionality emergence that occurs during ontogenetic development of an organism, as discussed in the previous subsection.

$$\begin{tikzcd} {[SUPER-COMPLEX]} \arrow[r, "\textbf{(Higher Dim)}"] \arrow[d, "\Lambda"'] & ULTRA-COMPLEX \arrow[d, "onto"] \\ COMPLEX & {[SIMPLE]} \arrow[l, "\textbf{(Generic Map)}"'] \end{tikzcd}$$

Note that the above diagram is indeed not 'natural' for reasons related to the emergent higher dimensions of the super–complex (biological/organismic) and/or ultra–complex (psychological/neural network dynamic) levels in comparison with the low dimensions of either simple (physical/classical) or complex (chaotic) dynamic systems. It might be possible, at least in principle, to obtain commutativity by replacing the simple dynamical system in the diagram with a quantum system, or a quantum 'automaton' (Baianu,1971,1987); however, in this case the diagram still does not necessarily close between the quantum system and the complex system with chaos, because it would seem that *quantum systems are 'fuzzy'*–not strictly deterministic– as complex 'chaotic' systems are. Furthermore, this categorical ontology diagram is neither recursively computable nor representable through a commutative algorithm of the kind proposed for Boolean neural networks (Healy and Caudell, 2006; for an extensive review of network biodynamic modelling, 'simulations' and also non-computability issues for biological systems see Baianu, 1986 and references cited therein). Note also that the top layer of the diagram has generic states and generic regions, whereas the lower layer does not; the top layer lives, the bottom one does not.

3.7.4. *Connectivity and Bionetwork Topology: Genetic Ontology and Interactomics Reconstruction.* One may place special emphasis on network topology and connectivity in Genetic Ontology and Categorical Biology since these concepts are becoming increasingly important in modern biology, as realized in rapidly unfolding areas such as post-Genomic Biology, *Proteomics* and *Interactomics* that aim at relating structure and protein-protein-biomolecule interactions to biological function. The categories of the biological/genetic/ecological/ levels may be seen as more 'structured' compared with those of the cognitive/mental levels (hinging on epiphenomenalism, interactive dualism, etc.) which may be seen as 'less structured', but not necessarily having less structural power owing to the increased abstraction in their design of representation. We are here somewhat in concert with Hartmann's (1952) laws of autonomy.

4. The Emergence of Life, Human Consciousness and Society.

With an increasing level of complexity generated through billions of years of evolution in the beginning, followed by millions of years for the ascent of man, and perhaps 10,000 more years for human societies and their civilizations, there is an increasing degree of *genericity* for the dynamic states of the evolving systems (Thom, 1980; Rosen, 2001). If such genericity is sufficient for the survival of the relatively very young human civilization is arguably one one of the most important human ontology questions. Evolutionary theories based only on historical evidence, and also without a dynamic foundation, cannot obviously answer this important question.

4.1. **What is Life ?** Although the distinction between living organisms and simple physical systems, machines, robots and computer simulations appears obvious at first sight, the profound differences that exist both in terms of dynamics, construction and structure require a great deal of thought, conceptual analysis, development and integration or synthesis. This fundamental, ontological question about Life occurs in various forms, possibly with quite different attempts at answers, in several books (e.g. Schrödinger, 1945; Rosen, 1995,1999).

4.1.1. *Emergence of Super-Complex Systems and Life. The 'Primordial' as the Simplest (M,R)- or Autopoietic-System.* In the preceding two sections we have already discussed from the categorical viewpoint several key systemic differences in terms of dynamics and modelling between living and inanimate systems. The ontology of super-complex biological systems, or biosystems (BIS), has perhaps begun with Elsasser's paper (1969) who recognized that organisms are extremely complex systems, that they exhibit wide variability in behaviour and dynamics, and also from a logical viewpoint, that they form– unlike physical systems– *heterogeneous classes.* (We shall use the 'shorthand' term *'biosystems'* to stand for super-complex biological systems, thus implicitely specifying the attribute super-complex within biosystems). This intrinsic BIS variability was previously recognized as *fuzziness* (Baianu and Marinescu, 1968) and some of its possible origins were suggested to be found in the partial structural disorder of biopolymers and biomembranes (Baianu, 1980). Yet other basic reasons for the presence of both dynamic and structural *'bio-fuzziness'* is the 'immanent' LM-logic in biosystems, such as functional genetic networks, and possibly also the Q-logic of signalling pathways in living cells. There are, however, significant differences between Quantum Logic, which is also non-commutative, and the LM-Logics of Life processes. Whereas certain reductionists would attempt to reduce Life's logics, or even human consciousness, to Quantum Logic (QL), the former are at least logically and algebraically *not reducible to QL.* Nonetheless, it may be possible to formulate QL through certain modifications of *non-commutative LM-logics* (Baianu, 2005; Baianu, Brown, Georgescu and Glazebrook, 2006).

Perhaps the most important attributes of Life are those related to the logics 'immanent' in those processes that are essential to Life. As an example, the logics and logic-algebras associated with functioning neuronal networks in the human brain–which are different from the multi–valued (Łukasiewicz–Moisil) logics (Georgescu, 2006) associated with functional genetic networks (Baianu, 1977, 1987; Baianu, Brown, Georgescu and Glazebrook, 2006) and self-reproduction (Lofgren,1968; Baianu, 1970; 1987)– were shown to be different from the simple Boolean-crysippian logic upon which machines and computers are built by humans. The former n-valued (LM) logics of functional neuronal or genetic networks are *non-commutative* ones, leading to *non-linear, super-complex* dynamics, whereas the simple logics of 'physical' dynamic systems and machines/automata are *commutative* (in the sense of involving a commutative lattice structure). Here, we find a fundamental, logical reason why living organisms are *non-commutative*, super-complex systems, whereas simple dynamical systems have *commutative modelling diagrams* that are based on *commutative Boolean* logic. We also have here the reason why a *commutative* Categorical Ontology of Neural networks leads to advanced robotics and AI, but has indeed little to do with the *'immanent logics'* and functioning of the living brain, contrary to the proposition made by McCulloch and Pitts (1943).

There have been several attempts at defining life in reductionistic terms and a few non-reductionist ones. Rashevsky (1968) attempted to define life in terms of the essential functional relations arising between organismic sets of various orders, i.e. ontological levels, beginning with genetic sets, their activities and products as the lowest possible order, zero, of on 'organismic set' (OS). Then he pursued the idea in terms of logical Boolean predicates (1969). Attempting to provide the simplest model possible he proposed the organismic set, or OS, as a basic representation of living systems, but he did not attempt himself to endow his OS with either a topological or categorical structure, in spite of the fact that he previously reported on the fundamental connection between Topology and Life (Rashevsky, 1959). He did attempt, however, a logical analysis in terms of formal symbolic logics and Hilbert's predicates. Furthermore, his PhD student, Robert Rosen did take up the challenge of representing organisms in terms of simple categorical models–his Metabolic-Repair,(**M,R**)-systems, or (**MR**)s (Rosen, 1958a,b). These two seminal papers were then followed by a series of follow up reports with many interesting, biologically relevant results and consequences in spite of the simplicity of the MR, categorical set 'structure'. Further extensions and generalizations of MR's were subsequently explored by considering abstract categories with both algebraic and topological structures (Baianu and Marinescu, 1973; Baianu, 1974, 1980a, 1984, 1987).

On the one hand, simple dynamical (physical) systems are often represented through groups of dynamic transformations. In GR, for example, these would be Lorentz–Poincare' groups of spacetime transformations/reference frames. On the other hand, super-complex systems, or biosystems, emerging through self-organization and complex aggregation of simple dynamical ones, are therefore expected to be represented mathematically–at least on the next level of complexity– through an extension, or generalization of mathematical groups, such as, for example, *groupoids*. Whereas simple physical systems with linear causality have high symmetry, a single energy minimum, and thus they possess only *degenerate* dynamics, the super-complex (living) systems emerge with lower symmetries but higher dynamic and functional/relational complexity. As symmetries get 'broken' the complexity degree increases sharply. From groups that can be considered as very simple categories that have just one object and reversible/invertible endomorphisms, one moves through 'symmetry breaking' to the structurally more complex groupoids, that are categories with many objects but still with all morphisms invertible. Dynamically, this reflects the transition from degenerate dynamics with one, or a few stable, isolated states ('degenerate' ones) to dynamic state regions of many generic states that are metastable; this multi-stability of biodynamics is nicely captured by the many objects of the groupoid and is the key to the 'flow of life' occurring as multiple transitions between the multiple metastable states of the homeostatic, living system. More details of how the latter emerge through biomolecular reactions, such as catabolic/anabolic reactions, will be presented in the next subsections, and also in the next section, especially under natural transformations of functors of biomolecular categories. As we shall see later in Section 3 the emergence of human consciousness as an ultra-complex process became possible through the development of the *bilaterally asymmetric* human brain, not just through a mere increase in size, but a basic change in brain architecture as well. Relationally, this is reflected in the transition to a higher dimensional structure, for example a double biogroupoid representing the bilaterally asymmetric human brain architecture, as we shall discuss further in Section 4. Therefore, we shall consider throughout the following sections various groupoids as some of the 'simplest' illustrations of the mathematical structures present in super-complex biological systems and classes thereof, such as *biogroupoids* (the groupoids featuring in bio–systems) and variable biogroupoids to represent evolving biological species. Relevant are here also *crossed complexes* of variable groupoids and/or *multi–groupoids* as more complex representations of biosystems that follow the emergence of ultra–complex systems (the mind and human societies, for example) from super-complex dynamic systems (organisms).

Furthermore, simple dynamic systems, or general automata, have *canonically decomposable semigroup* state spaces (the Krone-Rhodes Decomposition Theorem). It is in this sense also that recursively computable systems are 'simple', whereas organisms are not. In contrast, super-complex systems do not have state spaces that are known to be canonically decomposable, or partitioned into functionally independent subcomponent spaces, that is within a living organism all organs are inter-dependent and integrated; one cannot generally find a subsystem or organ which retains organismic life–the full functionality of the whole organism. However, in some of the simpler organisms, for example in *Planaria*, regeneration of the whole organism is possible from several of its major parts. We note here that an interesting, incomplete but computable, model of multi-cellular organisms was formulated in terms of 'cellular' or 'tessellation' automata simulating cellular growth in planar arrays with such ideas leading and contributing towards the 'mirror neuron system hypothesis' (Arbib, 2002). This incomplete model of 'tessellation automata' is often used in one form or another by seekers of computer-generated/algorithmic, artificial 'life'.

4.1.2. *Emergence of Organisms, Essential Organismic Functions and Life. The Primordial.* Whereas it would be desirable to have a complete definition of living organisms, the list of attributes needed for such a definition can be quite lengthy. In addition to super-complex, recursively non-computable and open system, there are several attributes employed to define living organisms, such as: auto-catalytic, self-organizing, structurally stable/generic, self-repair, self-reproducing, autopoietic, anticipatory, multi-level, and also possessing multi-valued logic. One needs to add to this list a number of processes that are thought to define life: irreversible processes coupled to bioenergetic processes and (bio)chemical concentration gradients, dissipative processes, inter-cellular flows, fluxes selectively mediated by semi-permeable biomembranes and thermodynamic linkage. These are of course just short lists that might be further condensed to a few key attributes and processes. However, some of these important attributes of organisms are inter-dependent and serve to define life categorically as a super-complex dynamic process that can have several alternate, or complementary descriptions/representations. Such descriptions can be formulated, for example, in terms of variable categories, variable groupoids, generalized Metabolic-Repair systems, organismic sets, hypergraphs, memory evolutive systems (MES), organismic toposes, interactomes, organismic super-categories and higher dimensional algebra. Each representation provides at present only a partial description of an organism, be it uni– or multi– cellular.

Organisms are thought of having all evolved from a simpler, 'primordial', proto-system or cell formed (how?) three, or perhaps four, billion years ago. Such a system, if considered to be the simplest, must have been similar to a bacterium, though perhaps without a cell wall, and also perhaps with a much smaller, single chromosome containing very few RNA 'genes' (two or, most likely, four).

We consider here a simple 'metaphor' of metabolic, self-repairing and self-reproducing models called (M,R)-systems, introduced by Robert Rosen (1958 a,b). Such models can represent some of the organismic functions that are essential to life; these models have been extensively studied and they can be further extended or generalized in several interesting ways. Rosen's simplest MR predicts one RNA 'gene' and just one proto-enzyme for the primordial 'organism'. An extended **MR** (Baianu, 1969; 1984) predicts however the primordial, PMR, equipped with a *ribozyme* (a telomerase-like, proto-enzyme), and this PMR is then also capable of ribozyme- catalized DNA synthesis, and would have been perhaps surrounded by a 'simple' lipid-bilayer membrane some four billion years ago. This can be represented by the following, very simple diagram:

$$A \xrightarrow{f} B \xrightarrow{\Phi} \Re[\mathsf{A},\mathsf{B}] \xrightarrow{\beta} \Re[\mathsf{B},\Re[\mathsf{A},\mathsf{B}]] \xrightarrow{\gamma} \ldots \longrightarrow \infty \ldots \tag{4.1}$$

where the symbol $\Re$ is the **MR** category representing the 'primordial' organism, PMR, and $\Re$[A,B] is the class of morphisms (proto-enzymes) bewteen the metabolic input class A (substrates) and the metabolic output class B (metabolic products of proto-enzymes). The ribozyme γ is capable of both catalizing and 'reverse' encoding its RNA template into the more stable DNA duplex, ∞. One can reasonably expect that such primordial genes were conserved throughout evolution and may therefore be found through comparative, functional genomic studies. The first ribozymes may have evolved under high temperature conditions near cooling volcanoes in hot water springs and their auto-catalytic capabilities may have been crucial for rapidly producing a large population of self-reproducing primordials and their descendant, *Archea*-like organisms.

Note that the primordial **MR**, or $PMR = \Re$, is an auto-catalytic, self-reproducing and autopoietic system; it can also be represented as an automaton (Warren, 1979). However, its 'evolution' is not entailed or enabled as yet; therefore, one needs define the primordial first as a variable biogroupoid or variable category, as we shall see in the following sections.

4.1.3. *An Example of an Emerging Super-Complex System as A Quantum–Enzymatic Realization of the Simplest **(M,R)**–System.* Note that in the case of either uni-molecular or multi-molecular, *reversible* reactions one obtains a *quantum-molecular groupoid*, QG, defined in terms of the variable molecular classes , or molecular class variables (mcv) and their *mcv–observables* (Baianu, 1984; Baianu et al 2007a). The mcv concept extends and expands the scope of molecular set theories (Bartholomay, 1960, 1965,1971). In the case of an enzyme, E, with an activated complex, $(ES)^*$, a *quantum biomolecuar groupoid* can be uniquely defined in terms of mcv–observables for the enzyme, its activated complex $(ES)^*$ and the substrate S. Quantum tunnelling in $(ES)^*$ then leads to the separation of the reaction product and the enzyme E which enters then a new reaction cycle with another substrate molecule S', indistinguishable–or equivalent to–S. By considering a sequence of two such reactions coupled together,

$$QG_1 \leftrightarrows QG_2 \ ,$$

corresponding to an enzyme f coupled to a ribozyme ϕ, one obtains a *quantum–molecular realization of the simplest **M,R**–system* (f, ϕ) ; see also the previous subsection for further details about the simplest primordial **MR/PMR** system.

The caveat here is that the relational systems considered above are *open* ones, exchanging both energy and *mass* with the system's environment in a manner which is dependent on time, for example in cycles, as the system 'divides'–reproducing itself; therefore, even though generalized quantum-molecular observables can be defined as specified above, neither a stationary nor a dynamic Schrödinger equation holds for such examples of 'super-complex' systems. Furthermore, instead of just energetic constraints–such as the standard quantum Hamiltonian–one has the constraints imposed by the diagram commutativity related to the mcv–observables, canonical functors and natural transformations, as well as to the concentration gradients, diffusion processes, chemical potentials/activities (molecular Gibbs free energies), enzyme kinetics, and so on. Both the canonical functors and the natural transformations defined above for uni- or multi- molecular reactions represent the relational increase in complexity of the emerging, super-complex dynamic system, such as, for example, the simplest (**M,R**)-system, (f, ϕ).

4.2. **Evolution and Dynamics of Systems, Organisms and Bionetworks: The Emergence of Increasing Complexity through Speciation and Molecular 'Evolution'/Transformations.** Although Darwin's Natural Selection theory has provided for more than 150 years a coherent framework for mapping the Evolution of species, it could not attempt to explain how Life itself has emerged in the first place, or even predict the rates at which evolution occurred/occurs, or even predict to any degree of detail what the intermediate 'missing links', or intervening species, looked like, especially during their ascent to man. On the other hand, Huxley, the major proponent of Darwin's Natural Selection theory of Evolution, correctly proposed that the great,'anthropoid' apes were perhaps 10 million years ago in man's ancestral line.

We note here that part of the answer to the question how did life first emerge on earth is suggested by the modelling diagram considered in Section 3 and the evolutionary taxonomy: it must have been the simplest possible organism, i.e., one that defined the minimum conditions for the emergence of life on earth. Additional specifications of the path taken by the emergence of the first super-complex living organism on earth, the 'primordial', come from an extension of **MR** theory and the consideration of its possible molecular realizations and molecular evolution (Baianu, 1984). The question still remains open: why primordial life–forms or super-complex systems no longer emerge on earth, again and again. The usual 'answer' is that the conditions existing for the formation of the 'primordial' no longer exist on earth at this point in time. Even though Evolutionary theories aim to encompass all organisms and species, their focus is on eukaryotic, multi–cellular organisms. There are very substantial differences, however between both the cellular and genome structures of prokaryotes and eukaryotes. Furthermore, bacteria and Archea are the oldest and most numerous surviving organisms on earth despite of their much simpler structures. The variability of living systems is so great, however, that organisms could evolve above the microscopic scale of bacteria, Archea and most uni-cellular algae. Because of the very rapid division rate of microorganisms and the very high 'evolutionary pressures' they are exposed to, the evolution of new strains of microrganisms can be now observed both in nature and in the laboratory; man has become able to control or directly generate new strains of microorganisms through genetic engineering and artificial selection. In spite of such progress being made, this does not mean at all that our understanding of bacterial life is anywhere close to being complete. In fact, in the 'race for survival' between man and antibiotic–resistant bacteria, the latter seem to be gaining new ground.

4.2.1. *Historical 'Continuity' in the Evolution of Super-Complex Systems: Topological Transformations and Discontinuities in Biological Development.* Anthropologists and evolutionary biologists in general have emphasized biological evolution as a *'continuous'* process, in a *historical*, rather than a topological, or dynamic sense. That is, there are historical sequences of organisms–phylogeny lines– which evolved in a well-defined order from the simpler to the more complex ones, with intermediate stages becoming extinct in the process that translates 'becoming into being', as Prigogine (1987) might have said. This picture of evolution as a 'tree of life', due initially and primarily to Wallace and Darwin, subsequently supported by many evolutionists, is yet to be formulated in *dynamic*, rather than historical, terms. Darwin's theory of *gradual* evolution of more complex organisms from simpler ones has been subject to a great deal of controversy which is still ongoing. If one were to accept for the moment Darwin's gradual evolution of species–instead of organisms– then, one may envisage the emergence of higher and higher *sub-levels* of super-complexity through biological evolution until a transition occurs through human society co-evolution to ultra-complexity, the emergence of human consciousness. Thus, without the intervention of human society co-evolution, a smooth increase in the degree of super-complexity takes place only until a distinct and discrete transition to the (higher) ultra-complexity level becomes possible through society co-evolution. If the previous process of increasing complexity–which occurred before the transition at the super-complexity level– were to be iterated also at the ultra-complex level, one might ask how and what will be the deciding factor for the further 'co-evolution of minds' and the transition towards still higher complexity levels? Of course, one might also ask first the contingent ontology question if any such higher level above human consciousness could at all come into existence? As shown in our recent report (Baianu et al 2007a), the emergence of levels, or sub-levels, of increasing higher complexity can be represented by means of *variable* structures of increasingly higher order or dimensions. There remains also the unresolved question why humans –as well as parrots–have the *inherited* inclination to talk whereas the apes do not; thus, a chimpanzee pup will not talk even if brought up in a human environment, whereas a human baby will first 'babble' and than develop early a 'motherese' talk as an intermediate stage in learning the adults' language; the chimpanzee pup never babbles nor develops any 'motherese' through natural interactions with either its own biological mother or with a human, surrogate mother. These facts seem to point to the absence in apes of certain brain structures, perhaps linked to mirror neurons, that are responsible for the human baby's inheritable *inclination* to babble (Wiener,1950/1989), which then leads to speech through learning and nurture in the human environment. Unlike physical and chemical studies, evolutionary ones are usually limited severely by the absence of controlled experiments to yield the prerequisite data needed for a complete theory. The pace of discoveries is thus much slower in evolutionary studies than it is in either physics or chemistry; furthermore, the timescale on which evolution has occurred, or occurs, is extremely far from that of physical and chemical processes occurring on earth, despite Faraday's saying that *"life is but a delayed chemical reaction"*. Such a multi-billion year timescale for evolution is a significant part of the evolution of the universe itself over some 18 billion years. Thus, interestingly, both Evolutionary and Cosmological studies work by quite different ontological and epistemologic means to uncover events that span across huge space-time regions. Whereas in Cosmology the view of an *absolute and fixed* Universe prevailed for quite a long time, it is currently accepted that the Universe 'evolves' as well as keeps rapidly inflating– it changes while very rapidly expanding relative to the observer or reference frame. Astrophysical studies have now established that our observable Universe is neither fixed nor absolute (thus validating Spencer's contention in 1862 of the absence of absolute space

and time). Similarly, Darwin's over-simplifying concepts of Natural Selection and Origin of species has survived for a surprisingly long time in biology and are still considered by many biologists as well-established 'fact' even today. 'Survival of the fittest' seems to have been, however Herbert Spencer's contribution to 'explaining' biological evolution, as well as society 'evolution' (in Spencer's opinion). On a much smaller space scale than Cosmology, biological evolution has also 'continuously' generated a vast, increasing number of species, however, with the majority of such species becoming extinct. In this latter process, geographical location, the climate, as well as occasional catastrophes (meteorites, volcanoes, etc.), seem to have played major roles. The historical view of biological evolution proposed by Darwin stems from the fact that every organism, or living cell, originates only from another, and there is no *de nuovo* re-starting of evolution. This raises two very important, related questions: *how did life start on earth in the first place? How did the first, primordial organism emerge some four billion years ago?* We shall see briefly how specific organismic models may provide some partial answers to these key questions left completely unanswered by Darwin's theory, or indeed any of its reductionist alternatives by neo-Darwinists.

4.2.2. *Biological Species. Evolving Species as Variable Biogroupoids.* After a century-long debate about what constitutes a biological species, taxonomists and general biologists seem to have now adopted the operational concept proposed by Mayr (1970):

> "a species is a group of animals that share a common gene pool and that are reproductively isolated from other groups."

Unfortunately, this concept is not readily applicable to extinct species and their fossils, the subject of great interest to paleoanthropologists, for example. From an ontology viewpoint, the biological species can be defined as a class of equivalent organisms from the point of view of sexual reproduction and or/functional genome, or as a *biogroupoid* (Baianu, Brown, Georgescu and Glazebrook, 2006). Whereas satisfactory as taxonomic tools these two definitions are not directly useful for understanding evolution. The biogroupoid concept, however, can be readily extended to a more flexible concept, the *variable groupoid*, which can be then utilized in theoretical evolutionary studies, and through predictions, impact on empirical evolutionary studies, as well as possibly organismic taxonomy.

For a collection of *variable groupoids* we can firstly envisage a parametrized family of groupoids $\{\mathsf{G}_\lambda\}$ with parameter λ (which may be a time parameter, although in general we do not insist on this). This is one basic and obvious way of seeing a variable groupoid structure. If λ belongs to a set M, then we may consider simply a projection $\mathsf{G} \times M \longrightarrow M$, which is an example of a trivial fibration. More generally, we could consider a *fibration of groupoids* $\mathsf{G} \hookrightarrow Z \longrightarrow M$ (Higgins and Mackenzie, 1990). However, we expect in several of the situations discussed in this paper (such as, for example, the metabolic groupoid introduced in the previous subsection) that the systems represented by the groupoid are interacting. Thus, besides systems modelled in terms of a *fibration of groupoids*, we may consider a multiple groupoid as defined as a set with a number of groupoid structures any distinct pair of which satisfy an *interchange law* which can be expressed as: each is a morphism for the other, or alternatively: there is a unique expression of the following composition:

$$\begin{bmatrix} x & y \\ z & w \end{bmatrix} \qquad \begin{array}{l} \longrightarrow j \\ \downarrow \\ i \end{array} \tag{4.2}$$

where i and j must be distinct for this concept to be well defined. This uniqueness can also be represented by the equation

$$(x \circ_j y) \circ_i (z \circ_j w) = (x \circ_i z) \circ_j (y \circ_i w). \tag{4.3}$$

This illustrates the principle that a 2-dimensional formula may be more comprehensible than a linear one!

Brown and Higgins (1981a) showed that certain multiple groupoids equipped with an extra structure called *connections* were equivalent to another structure called a *crossed complex* which had already occurred in homotopy theory. such as *double, or multiple* groupoids (Brown, 2004, 2005). For example, the notion of an *atlas* of structures should, in principle, apply to a lot of interesting, topological and/or algebraic, structures: groupoids, multiple groupoids, Heyting algebras, n-valued logic algebras and C^*-convolution -algebras. An example that may involve multiple groupoids in the ultra-complex system of the human mind is that of *synaesthesia*–the case of extreme communication processes between different types of 'logics' or different levels of 'thoughts'/thought processes. The key point here is *communication*. Hearing has to communicate to sight/vision in some way; this seems to happen in the human brain in the audiovisual (neocortex) and in the Wernicke (W) integrating area in the left-side hemisphere of the brain, that also communicates with the speech centers or the Broca area, also in the left hemisphere. Because of this *dual-functional*, quasi-symmetry, or more precisely asymmetry of the human brain, it may be useful to represent all two-way communication/signalling pathways in the two brain hemispheres by a *double groupoid* as an over-simplified groupoid structure that may represent such quasi-symmetry of the two sides of the human brain. In this case, the 300 millions or so of neuronal interconnections in the *corpum callosum* that link up neural network

pathways between the left and the right hemispheres of the brain would be represented by the geometrical connection in the double groupoid. The brain's overall *asymmetric* distribution of functions and neural network structure between the two brain hemispheres may therefore require a non-commutative, double–groupoid structure for its relational representation. The potentially interesting question then arises how one would mathematically represent the split-brains that have been neurosurgically generated by cutting just the *corpus callosum*– some 300 million interconnections in the human brain (Sperry, 1992). It would seem that either a crossed complex of two, or several, groupoids, or indeed a direct product of two groupoids G_1 and G_2, $G_1 \times G_2$ might provide some of the simplest representations of the human split-brain. The latter, direct product construction has a certain kind of built-in commutativity: $(a, b)(c, d) = (ac, bd)$, which is a form of the interchange law. In fact, from any two groupoids G_1 and G_2 one can construct a double groupoid $G_1 \bowtie G_2$ whose objects are $\mathrm{Ob}(G_1) \times \mathrm{Ob}(G_2)$. The internal groupoid 'connection' present in the double groupoid would then represent the remaining basal/'ancient' brain connections between the two hemispheres, below the corpum callosum that has been removed by neurosurgery in the split-brain human patients. The remarkable variability observed in such human subjects both between different subjects and also at different times after the split-brain (bridge-localized) surgery may very well be accounted for by the different possible groupoid representations.

The very common health problem caused by the senescence of the brain could be approached as a *local-to-global*, super-complex ageing process represented for example by the *patching* of a *topological double groupoid atlas* connecting up many local faulty dynamics in 'small' un–repairable regions of the brain neural network, caused for example by tangles, locally blocked arterioles and/or capillaries, and also low local oxygen or nutrient concentrations. The result, as correctly surmised by Rosen (1987), is a *global*, rather than local, senescence, super-complex dynamic process. On the other hand, for 'simple' physical systems it is quite reasonable to suppose that structures associated with symmetry and transitions could well be represented by 1–groupoids, whereas transitions between *quantum* transitions, could be then represented by a special type of quantum symmetry double groupoid that we shall call here simply a *quantum double groupoid* (QDG; Baianu, Brown and Glazebrook, 2007c), as it refers to *fundamental quantum* dynamic processes (cf. Werner Heisenberg, as cited by Brown, 2002).

Developmental processes, and in general, ontogeny considered from a structural or anatomical viewpoint involves not only geometrical or topology–preserving transformations but more general/complex transformations of even more flexible structures such as variable groupoids. The natural generalizations of variable groupoids lead to 'variable topology' concepts that are considered in the next subsection.

4.2.3. *Super–Complex Network Biodynamics in Variable Biogroupoid Categories. Variable Bionetworks with Variable Topology and their Super-Categories.* This section is an extension of the previous one in which we introduced variable biogroupoids in relation to speciation and the evolution of species. The variable category concept generalizes that of variable groupoid which can be thought as a variable category whose morphisms are invertible; the latter is thus a more 'symmetric' structure than the general variable category. Variable biogroupoids are also good models of biosystems–super-complex systems that in general have a varying topological structure, or variable topology. Thus, we realize here the basic reason for which organisms are super–complex: their dynamics can only be adequately characterized through a variable topology, or 'super–topology', HDA, etc. We have seen that variable biogroupoid representations of biological species may provide powerful tools for tracking evolution at the level of species. On the other hand, the representation of organisms, with the exception of unicellular ones, is likely to require more general structures, and super-structures of structures (Baianu, 1970). In other words, this leads towards higher-dimensional algebras (HDA) representing the super-complex hierarchies present in a complex–functional, multi-cellular organism, or in a highly-evolved functional organ such as the human brain. The latter (HDA) approach will also be discussed in the last section in relation to neurosciences and consciousness, whereas we shall address here the question of representing organisms regarded as (dynamic) biosystems in terms of variable categories that are lower in complexity than the ultra-complex human mind. A The range of applications for variable categories includes neurosciences, neurodynamics and brain development, in addition to the evolution of the simpler genomes and/or interactomes. Ultimately, it does lead directly to the more powerful 'hierarchical' structures of higher dimensional algebra.

4.2.4. *Variable Topologies.* Let us recall the basic principle that a *topological space* consists of a set X and a 'topology' on X where the latter gives a precise but general sense to the intuitive ideas of 'nearness' and 'continuity'. Thus the initial task is to axiomatize the notion of 'neighborhood' and then consider a topology in terms of open or of closed sets, a compact-open topology, and so on (see Brown, 2006). In any case, a topological space consists of a pair $(X, \mathcal{T})$ where $\mathcal{T}$ is a topology on X. For instance, suppose an *open set topology* is given by the set $\mathcal{U}$ of prescribed open sets of X satisfying the usual axioms (Brown, 2006 Chapter 2). Now, to speak of a variable open-set topology one might conveniently take in this case a family of sets $\mathcal{U}_\lambda$ of *a system of prescribed open sets*, where λ belongs to some indexing set Λ. The system of open sets may of course be based on a system of contained neighbourhoods of points where one system may have a different geometric property compared say to another system (a system of disc-like

neighbourhoods compared with those of cylindrical-type). In general, we may speak of a topological space with a varying topology as a pair $(X, \mathcal{T}_\lambda)$ where $\lambda \in \Lambda$. The idea of a varying topology has been introduced to describe possible topological distinctions in bio-molecular organisms through stages of development, evolution, neo-plasticity, etc. This is indicated schematically in the diagram below where we have an n-stage dynamic evolution (through complexity) of categories D_i where the vertical arrows denote the assignment of topologies $\mathcal{T}_i$ to the class of objects of the D_i along with functors $\mathcal{F}_i : \mathsf{D}_i \longrightarrow \mathsf{D}_{i+1}$, for $1 \leqslant i \leqslant n-1$:

$$\begin{tikzcd}
\mathcal{T}_1 \arrow[d] & \mathcal{T}_2 \arrow[d] & \cdots & & \mathcal{T}_{n-1} \arrow[d] & \mathcal{T}_n \arrow[d] \\
\mathsf{D}_1 \arrow[r, "\mathcal{F}_1"] & \mathsf{D}_2 \arrow[r, "\mathcal{F}_2"] & {} & \cdots & \mathsf{D}_{n-1} \arrow[r, "\mathcal{F}_{n-1}"] & \mathsf{D}_n
\end{tikzcd}$$

In this way a variable topology can be realized through such n-levels of complexity of the development of an organism. Another instance is when cell/network topologies are prescribed and in particular when one considers a categorical approach involving concepts such as *the free groupoid over a graph* (Brown, 2006). Thus a varying graph system clearly induces an accompanying system of variable groupoids. As suggested by Golubitsky and Stewart (2006), symmetry groupoids of various cell networks would appear relevant to the physiology of animal locomotion as one example.

4.2.5. *Quantum Genetic Networks and Microscopic Entropy.* Following Schrödinger's attempt (Schrödinger, 1945), Robert Rosen's report in 1960 was perhaps one of the earliest quantum–theoretical approaches to genetic problems that utilized explicitly the properties of von Neumann algebras and spectral measures/self–adjoint operators (Rosen, 1960). A subsequent approach considered genetic networks as *quantum automata* and genetic reduplication processes as *quantum relational oscillations* of such bionetworks (Baianu, 1971a). This approach was also utilized in subsequent reports to introduce representations of genetic changes that occur during differentiation, biological development, or oncogenesis in terms of *natural transformations of organismal (or organismic) structures* (Baianu,1980 to 1987a,b; 2004a,b; Baianu and Prisecaru, 2004), thus paving the way to a *Quantum Relational Biology* (Baianu, 1971a, 2004a). The significance of these results for quantum bionetworks was also recently considered from both a *logical and an axiomatic* viewpoint Baianu, Brown, Georgescu and Glazebrook, 2006). On the other hand, the extension of quantum theories, and especially quantum statistics, to non-conservative systems, for example by Prigogine (1987) has opened the possibility of treating *irreversible*, super-complex systems that vary in time and 'escape' the constraints of unitary transformations, as discussed above in Section 2. Furthermore, the latter approach allows the consideration of functional genetic networks from the standpoint of quantum statistics and microscopic entropy. Thus, information transfer of the 'genetic messages' throughout repeated somatic cell divisions may be considered either in a modified form of Shannon's theory of communication channels in the presence of 'noise', or perhaps more appropriately in terms of Kolmogorov's concept of entropy (see Li and Vitanyi, 1997). On the other hand, the preservation and/or repeated 'transmission' of genetic 'information' through germ cells– in spite of repeated quantum 'observations' of active DNA genes by replicase– is therefore an open subject that might be understood by applying the concept of microscopic entropy in Quantum Genetics.

4.2.6. *Lukasiewicz and LM-Logic Algebra of Genome Network Biodynamics. Quantum Genetics, Q-Logics and The Organismic LM–Topos.* The representation of categories of genetic network biodynamics **GNET**s as subcategories of LM–Logic Algebras (**LMA**s) was recently reported (Baianu, Brown, Georgescu and Glazebrook, 2006) and several theorems were discussed in the context of morphogenetic development of organisms. The **GNET** section of the cited report was a review and extension of an earlier article on the 'immanent' logic of genetic networks and their complex dynamics and non-linear properties (Baianu, 1977). Comparison of GNET universal properties relevant to *Genetic Ontology* can be thus carried out by colimit- and/or limit– preserving functors of GNETs that belong to adjoint functor pairs (Baianu and Scripcariu, 1974; Baianu, 1987; Baianu et al, 2006). Furthermore, evolutionary changes present in functional genomes can be represented by natural transformations of such universal–property preserving functors, thus pointing towards evolutionary patterns that are of importance to the emergence of increasing complexity through evolution; they can also lead to the emergence of the human organism. Missing from this approach, however, is a consideration of the important effects of social, human interactions in the formation of language, symbolism, rational thinking, cultural patterns, creativity, and so on... to full human consciousness.

The Organismic LM–Topos.

As reported previously (Baianu et al., 2006) it is possible to represent directly the actions of LM, many-valued logics of genetic network biodynamics in a categorical structure generated by selected LM–logics. The combined logico-mathematical structure thus obtained may have several operational and consistency advantages over the GNET-categorical approach of 'sets with structure'. Such a structure was called an 'LM-Topos' and represents a significant,

non-commutative logic extension of the standard Topos theory which is founded upon a commutative, intuitionist (Heyting-Brouwer) logic. The non-commutative logic LM–topos offers a more appropriate foundation for structures, relations and organismic or societal functions that are respectively super-complex or ultra-complex. This new concept of an LM–topos thus paves the way towards a Non-Abelian Ontology of highly complex spacetime structures as in organisms and societies.

4.2.7. *Natural Transformations of Evolving Organismic Structures. Generalized (M,R)-Systems as Variable Groupoids.* We have considered the important example of MR-Systems with *metabolic groupoid* structures (that is, *reversible enzyme reactions/metabolic functions–repair replication* groupoid structures), for the purpose of studying RNA, DNA, epigenomic and genomic functions. For instance, the relationship of

$$\text{METABOLISM} = \text{ANABOLISM} \Longrightarrow \Longleftarrow \text{CATABOLISM}$$

can be represented by a metabolic groupoid of *'reversible', anabolic/catabolic processes.* In this respect, the simplest MR-system can be represented as a *topological groupoid* with the open neighbourhood topology defined for the entire dynamical state space of the MR-system, that is an open/generic– and thus, a structurally stable– system, as defined by the dynamic realizations of MR-systems (Rosen, 1971a,b). This requires a descriptive formalism in terms of *variable groupoids* following which the human MR-system would then arise as the *colimit* of its complete biological family tree expressible in terms of a family of many linked/connected groupoids; this variable biogroupoid representation proves also to be useful in studies of evolution.

*A Simple Metabolic-Repair **(M,R)**–System with Reverse Transcription: An example of Multi-molecular Reactions Represented by Natural Transformations.*

We shall consider again the diagram corresponding to the simplest (**M, R**)-System realization of a Primordial Organism, PO. The RNA and/or DNA duplication and cell divisions would occur by extension to the right of the simplest MR-system, (f, Φ), through the $\beta : H(A, B) \to H(B, H(A, B))$ and $\gamma : H(B, H(A, B)) \to H(H(A, B), H(B, H(A, B)))$ morphism. Note in this case, the 'closure' entailed by the functional mapping, γ, that physically represents the regeneration of the cell's *telomere* thus closing the DNA-loop at the end of the chromosome in eukaryotes. Thus γ represents the activity of a *reverse transcriptase.* Adding to this diagram an hTERT suppressor gene would provide a *feedback* mechanism for an effective control of the cell division and the possibility of cell cycle arrest in higher, multi-cellular organisms (which is present only in *somatic* cells). The other alternative-which is preferred here-is the addition of an hTERT *promoter gene* that may require to be activated in order to begin cell cycling. This also allows one to introduce simple models of carcinogenesis or cancer cells. Rashevsky's hierarchical theory of organismic sets can also be constructed by employing mcv's with their observables and natural transformations as it was shown in a previous report (Baianu, 1980).

*Thus, one obtains by means of natural transformations and the Yoneda-Grothendieck construction a unified, categorical-relational theory of organismic structures that encompasses those of organismic sets, biomolecular sets, as well as the general **(M,R)**-systems/autopoietic systems which takes explicitly into account both the molecular and quantum levels in terms of molecular class variables* (Baianu, 1980, 1984, 1987).

Oncogenesis, Dynamic Programming and Algebraic Geometry .

In this section we shall discuss changes of normal controls in cells of an organism. It was previously proposed that certain specific changes of cellular controls occur in oncogenesis as a result of an initial abnormal human genome architecture (Baianu, 1969a; Baianu and Marinescu, 1969b). These changes may become permanent, if the basic relational oscillators of the cell have also been modified. In the language of qualitative dynamics this may be translated as a change of dominating attractors, followed by the inhibition or destruction of the former dominating attractors. This kind of change is not necessarily a mutation, that is, the change may not produce the replacement of some essential observables in the genetic system; this would however result eventually in many mutations and also alter the chromosomal architecture and modify the diploid arrangement of chromosomes in the cell nucleus. This may be the reason for which extensive research on cancers failed to discover so far a general, unique and specific alteration of the genetic system of cancer cells, *except for aneuploidy.* The change of basic relational oscillators in the genetic system may have such consequences as, for example, abnormally large nucleoli. The reason may be that a change in the subspace of the controller produces the change of dynamic programming of the whole cell. Dynamic programming consists in the existence of distinguished states, or policies in the subspace corresponding to the controller, to which correspond specific changes of trajectories in the subspace of the controlled subsystem. The appropriate mathematical concept corresponding to such situations is found in algebraic geometry. A projective space of n dimensions will be assigned to the controlled subsystem, and a policy would be then represented by an allowable coordinate system in the projective space of the controlled subsystem. *A projective space of n dimensions* is defined as a set of elements S (called the points of the space) together with another set Z (the set of allowable coordinate systems in the space). Let $(a_0, \ldots, a_n)$ be an $n + 1$–tuple of elements such that not all the elements

$a_0, \ldots, a_n$ are zero. Two $n+1$–tuples $(a_0, \ldots, a_n)$, $(b_0, \ldots, b_n)$ are said to be equivalent if there exists an element $\lambda \neq 0$ of a ground field $\mathbb{K}$ such that $a_i = \lambda b_i$ (for $i = 0, 1, \ldots, n$). A set equivalent $(n+1)$-tuples then a point of the projective space of dimension n over $\mathbb{K}$ where the latter is denoted by $P^n(\mathbb{K})$. If T denotes a correspondence among the elements of a set S and the points of $P^n(\mathbb{K})$, which is an isomorphism, then, to any element A of S, there corresponds a set of equivalent $(n+1)$-tuples $(a_0, \ldots, a_n)$, where $T(A)$ is $(a_0, \ldots, a_n)$. Any $(n+1)$–tuple of this set is called a set of coordinates of A (A set of equations written in matrix form as $y = Ax$ transforms $(n+1)$-tuples $(x_0, \ldots, x_n)$ into the set of equivalent (n + 1)-tuples $(y_0, \ldots, y_n)$. That is, equation (3) induces a map of $P^n(\mathbb{K})$ to itself. The set (3) of equations is called a *projective transformation* of $P^n(\mathbb{K})$ into itself. If S is the set from the definition of a projective space, then a projective transformation leads to a change of coordinate system in S. The different coordinate systems obtained through the application of different projective transformations are called *allowable coordinate systems* in S. Such coordinate systems define *policies of the controller.* In this case the set of all policies of a controller has the structure of a group as far as the projective transformations form a group.

Now, if there is an extension $\mathbb{K}_0$ of the ground field $\mathbb{K}$, and any h in $\mathbb{K}_0$, h will be called *algebraic* if there exists a non–zero polynomial $f(x)$ in $\mathbb{K}[x]$ such that $f(h) = 0$. The aggregate of points defined by the set of equations $f_\ell(x_0, \ldots, x_n) = 0$, with $f_\ell(x_0, \ldots, x_n)$ a homogeneous polynomial over $\mathbb{K}$, is called an *algebraic variety.* Thus, one can define a *dynamical program* in terms of algebraic varieties of a projective space corresponding to the subspace of the controlled subsystem, and with allowable coordinate systems (projective transformations) corresponding to policies in the subspace of the controller. Quantitative results concerning changes of controls in oncogenesis could be thus obtained on the basis of algebraic computations by algebraic geometrical methods (Baianu, 1971). A quantitative result which is directly suggested by this representation is the degree of synchrony in cultured cancer cells. The power of such computations and the elegance of the method is improved by means of the theory of categories and functors; this method of representation requires further investigation.

4.3. **Evolution as a Local-to- Global Problem: The Metaphor of Chains of Local Procedures. Bifurcations, Phylogeny and the 'Tree of Life'.** Darwin's theory of natural selection considers both specific and general biological functions such as adaptation, reproduction, heredity and survival, has been substantially modified and enriched over the last century. In part, this is due to more precise mathematical approaches to population genetics and molecular evolution which developed new solutions to the key problem of speciation (Bendall, 1982; Mayr and Provine, 1980; Pollard, 1984; Sober, 1984; Gregory, 1987). Modified evolutionary theories include neo–Darwinism, the 'punctuated evolution' (Gould, 1977) and the 'neutral theory of molecular evolution' of Kimura (1983). The latter is particularly interesting as it reveals that evolutionary changes do occur much more frequently in unexpressed/silent regions of the genome, thus being 'invisible' phenotypically. Therefore, such frequent changes ('silent mutations') are uncorrelated with, or unaffected by, natural selection. For further progress in completing a logically valid and experimentally-based evolutionary theory, an improved understanding of speciation and species is required, as well as substantially more extensive, experimental/genomic data related to speciation than currently available. Furthermore, the ascent of man, is apparently not the result of only natural selection but also that of co-evolution through society interactions. Thus, simply put: the emergence of human speech and consciousness occurred both through selection and co-evolution, with the former not being all that 'natural' as society played a protective, as well as selective role from the very beginnings of hominin and hominid societies more than 2.2 million years ago. Somewhat surprisingly, the subject of *social selection* in human societies is rarely studied even though it may have played a crucial role in the emergence of *H. sapiens*, and occurs in every society that we know, without any exception.

Furthermore, there is a theory of levels, ontological question that has not yet been adequately addressed, although it has been identified: *at what level does evolution operate: species, organism or molecular (genetic)?* According to Darwin the answer seems to be the species. However, not everybody agrees because in Darwin's time a valid theory of inherited characters was neither widely known nor accepted. Moreover, molecular evolution and concerted mutations are quite recent concepts whose full impact has not yet been realized. As Brian Goodwin (2002) puts it succinctly:

> '*'Where has the organism disappeared in Darwin's evolutionary theory?"*

The answer in both Goodwin's opinion, and also in ours, lies in the presence of key functional/relational patterns that emerged and were preserved in organisms throughout various stages over four billion years or so of evolution. The fundamental relations between organism, species and the speciation process itself do need to be directly addressed by any theory that claims to explain the evolution of species and organisms. Furthermore, an adequate consideration of the biomolecular levels and sub-levels involvement in speciation and evolution must also be present in any improved evolutionary theory. These fundamental questions were considered from the categorical ontology viewpoint in a recent report (Baianu et al, 2007a).

In his widely read book, D-Arcy W. Thompson (1994, re-printed edition) gives a large number of biological examples of organismic growth and forms analyzed at first in terms of physical forces. Then, he is successful in carrying out analytical geometry coordinate transformations that allow the continuous, homotopic mapping of series of species that are thought to belong to the same branch–phylogenetic line– of the tree of life. However, he finds it very difficult or almost impossible to carry out such transformations for fossil species, skeleton remains of species belonging to different evolutionary branches. Thus, he arrives at the conclusion that the overall evolutionary process is not a continuous sequence of organismic forms or phenotypes (see p. 1094 of his book).

Thus, one needs to address the question of super-complex systems' evolution as a *local-to-global* problem instead of a topologically continuous process. We are then seeking solutions in terms of the novel categorical concepts that were sketched in the previous subsections and also exactly defined in recent reports (Brown et al, 2007a; Baianu et al, 2007a). Therefore, we consider here biological evolution by introducing the unifying metaphor of *'local procedures'* which may represent the formation of new species that branch out to generate still more evolving species. Because genetic mutations that lead to new species are discrete changes, we are therefore not considering evolution as a series of continuous changes–such as a continuous curve drawn analytically through points representing species –but heuristically as a *tree of 'chains of local procedures'* (Brown, 2006). Evolution may be alternatively thought of and analyzed as a *composition of local procedures*. Composition is a kind of combination and so it might be confused with a colimit, but they are substantially different concepts. Therefore, one may attempt to represent biological evolution as an evolutionary tree, or 'tree of life', with its branches completed through chains of local procedures (pictured in Figure 3.4.1 as overlapping circles) involving certain groupoids, previously defined as *variable topological biogroupoids* in Baianu et al, (2007a). The overlaps in this latter representation correspond to 'intermediate' species or classes/populations of organisms which are rapidly evolving under strong evolutionary pressure from their environment (including competing species, predators, etc., in their niche).

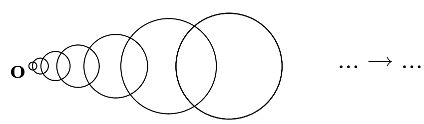


Figure 4.3.1: A pictorial representation of Biological Evolution as a composition of local procedures involving variable biogroupoids that represent biological speciation phenomena. COLPs may form the branches of the evolutionary tree, oriented in this diagram with the time arrow pointing to the right.

The notion of 'local procedure' is an interpretation of Ehresmann's formal definition of a *local admissible section* s for a groupoid G in which $X = \mathrm{Ob}(G)$ is a topological space. Then s is a section of the source map $\alpha : G \to X$ such that the domain of s is open in X. If s, f are two such sections, their composition st is defined by $\mathsf{st}(x) = \mathsf{s}(\beta t(x)) \circ t(x)$ where $\circ$ is the composition in G. The domain of st could also be empty. One may also put the additional condition that s is 'admissible' , namely $\beta\mathsf{s}$ maps the open domain of s homeomorphically to the image of $\beta\mathsf{s}$, which itself is open in X. Then an admissible local section is *invertible* with respect to the above composition. A tree-graph that contains only single-species biogroupoids at the 'core' of each 'local procedure' does define precisely an evolutionary branch without the need for subdivision because a species is an 'indivisible' entity from a breeding or reproductive viewpoint. Several different concepts in organismic dynamics, stability and variability 'converge' here on the metaphor of (chains of) 'local procedures' for evolving organisms and species. Such distinct representations are: the dynamic genericity of organismic states which lead to structural stability, the logical class heterogeneity of living organisms, and the inherent 'bio–fuzziness' of organisms (Baianu and Marinescu, 1968) in both their structure and function; or they can also considered as autopoietic models of the 'structural variability' exhibited by living systems (Maturana, 1980), imposed to the organisms through their couplings with a specific environmental niche.

This novel, *dynamic* rather than historic/Darwinist intuition of evolution may be difficult to grasp at first as it involves several construction stages on different ontological levels: it begins with organisms (or possibly even with biomolecular categories), emerges to the level of populations/subspecies/ species that evolved into classes of species, that had then further evolved, ...and so on. Finally, it reaches the point in time where the emergence of man's, *Homo* family of species began to separate from other hominin/hominide families of species some 5 to 8 million years ago. One concludes in agreement with Robert Rosen's ideas (personal communication to ICB in 1970) that the evolutionary processes operate on several different levels/sublevels of reality, on different time scales; it is now generally accepted that speciation is also aided by geographical barriers or geological accidents. This highly complex, dynamic reality of the emerging higher levels of complexity is quite different from that in Darwin's widely acclaimed "Origin of Species", and it is also a much more powerful concept than Spencer's vague evolutionary speculations in his several books on philosophical principles (1898); furthermore, it also includes– but is not limited to– Goodwin's excursions

into contingent, 'chaotic complexity' (1994, 2000). The following subsection links up our novel evolutionary model with recently emerging autopoiesis models, and their earlier, corresponding Rosen's **MR-**systems.

4.3.1. *Autopoiesis Models of Survival and Extinction of Species through Space and Time.* The autopoietic model of Maturana (1987) claims to explain the persistence of living systems in time as the consequence of their structural coupling or *adaptation* as structure determined systems, and also because of their existence as *molecular* autopoietic systems with a 'closed' network structure. As part of the autopoietic explanation is the 'structural drift', presumably facilitating evolutionary changes and speciation. One notes that autopoietic systems may be therefore considered as dynamic realizations of Rosen's simple **MR** s. Similar arguments seem to be echoed more recently by Dawkins (2003) who claims to explain the remarkable persistence of biological organisms over geological timescales as the result of their intrinsic, (super-) complex, adaptive capabilities. The point is being often made that it is not the component atoms that are preserved in organisms (and indeed in 'living fossils' for geological periods of time), but the *structure-function relational pattern*, or indeed the associated organismic categories/ supercategories. This is a very important point: only the functional organismic structure or pattern persists as it is being conserved and transmitted from one generation to the next. Biomolecules turn-over in an organism, and not infrequently, but the *structure-function patterns/organismic categories remain unchanged*/are conserved over long periods of time through repeated repairs and replacements of the molecular parts that need repairing, as long as the organism lives. Such stable patterns of relations are, at least in principle, amenable to logical and mathematical representation without tearing apart the living system. Hence the relevance here, and indeed the great importance of the science of abstract structures and relations, i.e., Mathematics. In fact, looking at this remarkable persistence of certain gene subnetworks in time and space from the categorical ontology and Darwinian viewpoints, the *existence of live 'fossils'* (e.g., a coelacanth found alive in 1923 to have remained unchanged at great depths in the ocean as a species for 300 million years!) it is not so difficult to explain; one can attribute the rare examples of 'live fossils' to the lack of 'selection pressure in a very stable niche'. Thus, one sees in such exceptions the lack of any adaptation apart from those which have already occurred some 300 million years ago. This is by no means the only long lived species: several species of marine, giant unicellular green algae with complex morphology from a family called the *Dasycladales* may have persisted as long as 600 million years (Goodwin, 1994), and so on. However, the situation of many other species that emerged through *super-complex adaptations*–such as the species of *Homo sapiens*–is quite the opposite, in the sense of marked, super-complex adaptive changes over much shorter time–scales than that of the exceptionally 'lucky' coelacanths. Clearly, some species, that were less adaptable, such as the Neanderthals or *Homo erectus*, became extinct.

4.4. **The Emergence of *Homo sapiens* and Human Society.** . We are briefly considering here the tenuous evidence for the emergence of the *Homo sapiens* species– the Ascent of Man. The related question of the development of syntactically–structured speech through social *co-evolution* is also addressed in this section. Thus, the formation of the first human societies were apparently closely correlated with efficient communication through structured speech; on the other hand, the propagation, further development and indeed elaboration of speech was both made possible and sustained only through social interactions in the pre-historic human societies.

4.4.1. *Biological Evolution of Hominins (Hominides.)* Studies of the difficult problem of the emergence of man have made considerable progress over the last 50 years with a series of several key hominide/hominin fossils being found, such as: *Australopithecines, Homo erectus,* and *Homo habilis* being found, preserved, studied and analyzed in substantial detail. *Hominini* is defined as the tribe of *Homininae* that only includes humans (*Homo*), chimpanzees (*Pan*), and their extinct ancestors. Members of this tribe are called *hominins* (cf. Hominidae or 'hominids'). Humans, on the other hand are: of the Kingdom: Animal; Phylum: Chordate; Class: Mammal; Order: Primate;...
; Tribe: hominin. The Tribe hominini describes all the human/ human-line species that have ever evolved (including the extinct ones) which excludes the chimpanzees and gorillas. On the other hand, the corresponding, old terminology until 1980 was 'hominides', now hominoides. Among these, *Homo erectus* (and *H. ergaster*) were probably the first hominins to form a hunter gatherer society. Even though *H. erectus* used more sophisticated tools than the previous hominin species, the discovery of the Turkana boy in 1984 has produced the very surprising evidence that despite the *H. erectus*'s human-like skull and general anatomy, it was disappointingly incapable of producing sounds of the complexity required for either, ancient ($\prec$ 8,000 BC) or modern, elaborate speech. Therefore, it seems that *H. erectus* may not have topped the super-complexity threshold level towards the next level–that of human consciousness. Thus, *H. sapiens* stands up as the only remaining species which is *unique* in its vocal (speech) and mental (reasoning) abilities.

4.4.2. *The Ascent of Man through Social Co-Evolution. The Evolution of the Human Brain. Emergence of Human Elaborate Speech and Consciousness.* As stated above, there seems to be little doubt that a 'human–like' brain already was shaping up in *Homo erectus*, *ergastus*, or the Neanderthals but none of these preceding hominides are currently thought to have been able to speak, think, or have a consciousness of their own 'selves'. Following *Homo*

erectus, however, some apparent and temporary slowing down of hominin biological evolution may have occurred over the next 2 million years or so for hominides other than *H. sapiens* which according to some anthropologists separated as a species from a common ancestor with *H. ergastus* about 2.2 million years ago.

Therefore, the human brain considered as a biological organ, or subsystem, must have evolved *before* the highly coherent conscious states of the ordered mind of low informational entropy that emerged later through social co-evolution. The human mind is therefore proposed here to be represented by an *ultra–complex* 'system of processes' based on, *but not necessarily reducible to*, the human brain's super-complex level of activities that both enable and entail the emergence of the human mind's own consciousness. Thus, an attempt is made here to both define and represent in categorical ontology terms the human consciousness as an *emergent/global, ultra-complex process* of mental activities as distinct from–but correlated with–a multitude of integrated local super-complex processes that occur in the human brain. It has been suggested (Arbib, 2003)–with some evidence from certain experiments– that mirror neurons may mediate the social interactions leading to coherent, rational and elaborate speech, that thereafter supports the emergence of consciousness. Thus, the emergence of symbolic language with syntax, and the whole social co-evolution and progression towards consciousness may have accelerated only through the *unique* appearance of *H. sapiens*. Other hominin species, such as for example the Neanderthals, did not seem to have been able to catch up with *H. sapiens* and did not evolve beyond very primitive, small hunter–gatherer groups. Stronger evidence for the appearance of the coherent human speech comes only from the discoveries of the pre-historic Cro–Magnon man some 60,000 years ago. This leads one to assume that a very rapid 'transition' either occurred or began *from super- to ultra- complexity*, from biologically-based evolution to the societally-based 'co-evolution' of human consciousness but only after the birth of *H. sapiens* species. This relatively, very high rate of development through *societal-based 'co-evolution'* in comparison with the rather slow, preceding biological evolution is consistent with consciousness 'co-evolving' rapidly as the result of primitive societal interactions that have acted nevertheless as a powerful, and seemingly essential, 'driving force', 'catalyst' or stimulus. On the other hand, one may expect that the degree of complexity of human primitive societies which supported and promoted the emergence of human consciousness was also significantly higher than those of hominin bands characterized by what one might call individual *hominin 'quasi–consciousness'*. Passing the threshold towards human consciousness and awareness of the human self may have occurred –with any degree of certainty–only with the ascent of the *Cro–Magnon* man which is thought to belong to the modern species of *Homo sapiens sapiens*, (chromosomally descended from the Y haplogroup F/mt haplogroup N populations of the Middle East). This important transition seems to have taken place between 60,000 and 10,000 years ago through the formation of Cro–Magnon, human 'societies'–perhaps consisting of small bands of 25 individuals or so sharing their hunting, stone tools, wooden or stone weapons, a fire, the food, a cave, one large territory, and ultimately reaching human consensus.

After human consciousness fully emerged along with complex social interactions within pre–historic *H. sapiens* tribes, it is likely to have acted as a positive feedback on both the human individual and society development through multiple social interactions, thus leading to an ever increasing complexity of the already ultra-complex system of the first historic human societies appearing perhaps some 10,000 years ago. As in the case of the primordial, the question is raised if *H. sapiens* might have evolved in different places at different times, and is also answered in the negative, thus supporting uniqueness.

The claim is defended here that the emergence of ultra-complexity required the occurrence of '*symmetry breaking*' at several levels of underlying organization, thus leading to the unique *asymmetry* of the human brain–both functional and anatomical; such recurring symmetry breaking may also require a sharp complexity increase in our representations of mathematical-relational structure of the human brain and also human consciousness. Arguably, such repeated symmetry breaking does result in *layered complexity dynamic patterns* (Baianu and Poli, 2008; Poli, 2006c) in the human mind that appear to be organized in a hierarchical manner. Thus, 'conscious planes' and the focus of attention in the human mind are linked to an emergent *context-dependent variable topology* of the human brain, which is most evident during the brain's developmental stages guided by environmental stimuli such as human/social interactions; the earliest stages of a child's brain development would be thus greatly influenced by its mother.

4.4.3. *Memory and the Emergence of Consciousness.* Although the precise nature of human memory is unknown one may hypothesize that it involves processes that induce and regulate, or control the formation of higher levels of memory accessible to consciousness from the culmination of those at lower stages that may not be accessible to the conscious mind. Just as chemical reactions and syntheses engage canonical functors to build up neural networks (Baianu 1972, 1987), and natural transformations between them can enable 'continuous' perceptions, the various neural dynamic super-network structures– at increasingly higher levels of complexity– may support the dynamic emergence of the *continuous, coherent and* global *'flow of human consciousness'* as a new, *ultra-complex level of the mind*–as clearly distinct from, but also linked to– the underlying human brain's localized neurophysiological processes. Clearly, however, consciousness without memory is virtually impossible, but the reverse may not be

necessarily true as even an individual neuron retains at least a transient 'memory' of the most recent history of its stimuli.

4.4.4. *Local-to-Global Relations: A Higher Dimensional Algebra of Hierarchical Space/Time Models in Neurosciences. Higher-Order Relations (HORs) in Neurosciences and Mathematics.* The Greeks devised *the axiomatic method*, but thought of it in a different manner to that we do today. One can imagine that the way Euclid's Geometry evolved was simply through the delivering of a course covering the established facts of the time. In delivering such a course, it is natural to formalize the starting points, and so arranging a sensible structure. These starting points came to be called *postulates, definitions and axioms*, and they were thought to deal with real, or even ideal, objects, named points, lines, distance and so on. The modern view, initiated by the discovery of non–Euclidean geometry, is that the words points, lines, etc. should be taken as undefined terms, and that axioms give the *relations* between these. This allows the axioms to apply to many other instances, and has led to the power of modern geometry and algebra. Clarifying the meaning to be ascribed to 'concept', 'percept', 'thought', 'emotion', etc., and above all the *relations* between these words, is clearly a fundamental but time–consuming step. Although relations–in their turn–can be, and were, defined in terms of sets, their axiomatic/categorical introduction greatly expands their range of applicability well–beyond that of set-relations. Ultimately, one deals with *relations among relations* and relations of higher order. We are thus considering here the possibility of a novel higher-dimensional algebra approach to spacetime ontology and also to the dynamics of the human brain and the meta–level of the human mind. The human brain is perhaps one of the most complex systems –a part of the human organism which has evolved about two million years ago as a separate species from those of earlier *hominins/hominides*. Linked to this apparently unique evolutionary step– the evolution of the *H. sapiens* species– human consciousness emerged and co-evolved through *social* interactions, elaborate *speech*, *symbolic communication/language* somewhere between the last 2.2 million and 60,000 years ago. We shall thus consider in our essay the dynamic links between the biological, mental and social levels of reality. The most important claim defended here is that the *ultra-complex* process of processes (or meta-process) usually described as *human consciousness* is correlated with certain functions of fundamentally *asymmetric* structures in the human brain and their corresponding, recursively non–computable dynamics/psychological processes. These are *non-commutative* dynamic patterns of structure-function and can be therefore represented by a Higher Dimensional Algebra of neurons, neuronal (both intra- and inter-) signaling pathways, and especially high-level psychological processes viewed as *non-computable patterns* of linked-super-aggregate processes of processes,...,of still further sub-processes. Therefore, a local-to-global approach to Neural Dynamics and the human brain functions seems to be necessary based upon the essential dynamic relations that occur between the hierarchical layers of neural structures and functions in the brain; the emphasis here will be primarily on the human brain functions/biodynamics. We shall consider certain essential relations in Neurosciences and Mathematics as a potential starting point for a Categorical Ontology of Neurosciences. We conclude here that contrary to previous philosophical and ontological thinking, *low-level* relations are quite *insufficient* to define or understand consciousness, which is intrinsically based on meta–level, ***higher order relations (HORs)***, such as those involved in meta–processes of processes. Rather than being 'immaterial', the mind's meta-level works through such HORs, thus subsuming the lower order relations and processes to do its bidding without any need for either 'mystical'/'spiritualistic' pseudo–explanations or an equally baffling/inconceivable (human) mind–brain split with no physical connections between them. This extremely important theme will be further discussed in the remaining sections.

4.5. **What is Consciousness?** The problem of how the human mind and brain are related/correlated with each other has indeed many facets, and it can be approached from many different starting points. Herbert Spencer (1898) simply 'defined' consciousness as a ***relation*** between a 'subject' and an 'object'. Over the last twenty five years considerable attention has been paid to the question of whether or not mental processes have some physical content, and if not, how do they affect physical processes. It would seem however that previously not all the 'right', or key, questions have been asked about human consciousness. We have seen in the previous subsection that the meta–level question can be answered in the context of consciousness by HORs; Spencer's vague idea of a simpler, lower relation is insufficient here because of the general/fundamental asymmetry or distinction between 'object' and 'subject': an external object can often be defined in terms of simpler relations than those of the meta–level of the 'subject'. On the other hand, when the human mind becomes itself the 'object' of study by the 'subject', both are characterized by (albeit different) *meta–level* relations, and one also needs to consider then the *next higher order relations* (NHORs) between such meta-level relations. (As in Category Theory, simple morphisms are insufficient; the 'raison d' être' of mathematical categories are the *natural transformations*/functorial morphisms between functors, which as explained above are defined only on the second order meta–level, and thus involve NHORs.) Awareness, or self–consciousness, would then *a fortiori* involve such NHORs. Thus, both consciousness of others and the consciousness of one's self involve such ultra–complex NHOR's that are part and parcel of HDA; as we shall see later, the consciousness of others developed first through primitive human, social (tribal) interactions,followed by self-consciousness on the

same ultra–complex level of reality. As we shall see, this view is consistent with both recent philosophical psychology and with sociological enquiries into primitive *H. sapiens* tribes.

Historically, the leading disciplines concerned with the mind have been philosophy and psychology, later joined by behavioral science, cognitive science, logics, biomathematics, neuroscience and neural net computing. In addition, the physics of complex systems and quantum physics have produced stimulating discussions on the nature of consciousness. On the other hand, The study of neural networks and their relation to the operation of single neurons can profit a great deal from complex systems dynamic approaches. There is however no substantial, experimental evidence that quantum processes in the brain are *directly* correlated with any mental activity. One also has to pose here the related important question–as Deacon (1997) did: *why don't animals have language?* Some mammals, for example, show good evidence of intelligence in many other respects, yet fluent, symbolic language with meaning is altogether beyond their abilities. Parrots can learn only to repeat, but not generate meaningful, short sentences. Deacon also examined what it is unique about the human brain that makes it capable of symbolic speech with meaning. Unlike, Mumford (1958) however, Deacon seems to have missed the important point of the rhythmic dances and symbolic rituals in primitive human societies as the turning point for ordering and training the emerging human mind coupled to an orderly society in which reification has most likely played also the key role in the further co–evolution/advancement of the mind, the language and the human society. This latter, 'magic' triangle was not considered by Deacon; he only considered the human brain $\rightleftarrows$ language co–evolution, and did not seem to appreciate the role(s) played by the primitive human societies in the development of the unique human mind and consciousness.

Attempting to define consciousness runs into similar problems to those encountered in attempting to define Life; there is a long list of attributes of human consciousness from which one must decide which ones are the essential ones and which ones are derived from the primary attributes. Human consciousness is *unique*– it does not share its essential attributes with any other species on earth. It is also unique to each human being even though, in this case, certain 'consensual'/essential attributes do exist, such as, for example, *reification*. We shall return to this concept later in this section.

William James (1958) in "Principles of Psychology" considered consciousness as *"the stream of thought"* that never returns to the same exact 'state'. Both *continuity* and *irreversibility* are thus claimed as key, defining attributes of consciousness. We note here that our earlier metaphor for evolution in terms of 'chains of local (mathematical) procedures' may be viewed from a different viewpoint in the context of human consciousness–that of chains of 'local' thought processes leading to global processes of processes..., thus emerging as a 'higher dimensional' stream of consciousness. Moreover, in the monistic –rather than dualist–view of ancient Taoism the individual flow of consciousness and the flow of all life are at every instant of time interpenetrating one another; then, Tao in motion is constantly *reversing* itself, with the result that consciousness is *cyclic*, so that everything is –at some point– without fail changing into its opposite. One can visualize this cyclic patterns of Tao as another realization of the Rosetta biogroupoids that we introduced earlier in a different context– relating the self of others to one's own self. Furthermore, we can utilize our previous metaphor of 'chains of local procedures' –which was depicted in Figure 4.4.1–to represent here the "flow of all life" (according to Tao for example) not only in biological evolution, but also in the case of the generic local processes involving sensation, perception, logical/'active' thinking and/or meditation that are part of the 'stream of consciousness' (as described above in dualist terms). There is a significant amount of empirical evidence from image persistence and complementary color tests in perception for the existence of such cyclic patterns as those invoked by Tao and pictorially represented by the Rosetta biogroupoids in our Diagram 4.9.1; this could also provide a precise representation of the ancient Chinese concept of "Wu-wei" –literally 'inward quietness'–the perpetual changing of the stream of both consciousness and the unconscious into one another/each other. 'Wu', in this context, is just awareness with no conceptual thinking. Related teachings by Hui-neng can be interpreted as implying that *"consciousness of what is normally unconscious causes* both *the unconscious and consciousness to change/become something else than what they were before"*.

The important point made here is that there is a very wide spread of philosophical approaches, ranging from the Western duality to the 'neutral monistic' (Spencerian), and the Eastern (monistic) views of Consciousness and Life. On the other hand, neither the Western nor the Eastern approaches discussed here represent the only existing views of human consciousness, or even consciousness in general. The Western 'science' of consciousness is divided among several schools of thought: *cognitive psychology*–the mainstream of academic orientation, the *interpretive psychoanalytic tradition*, *the 'humanistic' movement*, and finally, the *trans–personal psychology* which focuses on practices towards 'transcendence' in the sense of 'beyond consciousness', rather than with the Kantian meaning of 'beyond phenomenal experience'.

4.6. **The Emergence of Human Consciousness as an Ultra-Complex, Meta–$<System>$ of Processes and Sub-processes.** The *ultra–complexity level* is defined in our essay as *the human mind's meta–level*, or the mental level, which comprises certain, unique dynamic patterns; it is conceived as *meta–process* of layered sub–processes,

emerging to the most complex level of reality known thus far to man (considered as 'the mind–subject' observing other 'minds–objects'). This meta-level emerges from and interacts with the super–complex activities and the higher level processes that occur in special, super-complex subsystems of the human brain; such brain, or neural proceses that were discussed in the previous section seem to be coupled through certain synergistic and/or mimetic interactions in human societies. In this sense, we are proposing a non–reductionist, categorical ontology that possesses both universal attributes and a top level of complexity encompassed only by human consciousness. However, several species seem also to possess subject awareness even though the individual nature of awareness differs dramatically *de facto* from that of *H. sapiens*. Whereas states of the mind, intention, qualia etc. are ingredient factors of consciousness that instantaneously occur with subjective awareness, none of these seem to be essential for the latter. Bogen (1995) discusses the neurophysiological aspect of *awareness* in relationship to the intra–laminar nuclei (ILN) which is a critical site when normal consciousness is impaired as the result of thalamic injury. However, his conclusions remain so far as speculative as many other so–called 'mechanisms' of consciousness.

As a working hypothesis, we propose a provisional, and quite likely incomplete, definition of human consciousness as an *ultra–complex* process integrating numerous super-complex 'sub-processes' in the human brain that are leading to a *'higher-dimensional ontological, mental level'* capable of: 'free will', new problem solving, and also capable of speech, logical thinking, generating new conceptual, abstract, emotional, etc., ontological structures, including –but not limited to–'awareness', self, high-level intuitive thinking, creativity, sympathy, empathy, and a wide variety of 'spiritual' or 'mental' *introspective* experiences. It may be possible to formulate a more concise definition but for operational and modelling purposes this will suffice, at least provisionally. The qualifier *'ultra-complex'* is mandatory and indicates that the ontological level of consciousness, or mental activities that occur in the conscious, '(psychological) state', is *higher* than the levels of the underlying, *super-complex* neurodynamic sub-processes leading to, and supporting, consciousness. On this view, although the mental level cannot exist independently without, or be existentially separated from the neurodynamics, it is nevertheless distinct from the latter. This looks like a Boolean logic paradox which is avoided if one considers human consciousness and/or the mind as a **meta–<system>** of intertwined mental and neurodynamic processes; such a meta-<system> would have no boundary in the sense described in Section 3, but a horizon. This proposed solution of the 'hard problem' of psychology is neither dualistic (i.e., Cartesian) nor monistic –as in Taoism or Buddhism; our novel view simply disagrees in detail with Descartes' dualism, Buddhist monism, and also with singularily ontic materialism, as it is an anti-thesis of *"tertium non datur"*– the excluded third possibility, simply because reality is likely to be much more complex than crysippian/ Boolean logic, as Hegel– as well as Buddhist philosophers– were very fond of repeatedly and correctly pointing out. It is also consistent with Kant's warnings in his critique of pure reason and his findings/logical proofs of formally undecidable propositions that preceded by three centuries Gödel's theorem (restricted to the incompleteness of arithmetics). Clearly, self-representation, self-awareness and the origin of symbolic meaning/semantics in general is resolved without any of the Russellian paradoxes of type as the meta–system has a different essence and existence than the various systems of processes from which it emerged; one is therefore obliged to consider the ultra–complex, ontology level, a **meta–level** of existence. (See also subsection **3.5.3** on meta-theorems for the mathematical meaning of this term.)

A methaporical comparison is here proposed of consciousness with the mathematical structure of a ('higher dimensional') *double* groupoid constructed from a 'single' topological groupoid–that would, through much over-simplifying, represent the topology of the human brain network processes (occurring in the two interconnected brain hemispheres) which lead to consciousness. In order to obtain a sharper, more 'realistic' (or should one perhaps say instead, 'ideal') representation of consciousness one needs consider psychological 'states' (Ψ), 'structures' (Φ) as well as consciousness modes (CMs) in addition, or in relation to neurophysiological network structure and neural network super-complex dynamics. According to James (W., 1890), consciousness consists in a *'continuous stream or flow'* of psychological 'states' which never repeats the same 'state' because it is continually changing through the interaction with the outer world, as well as through internal thought processes (suggested to have been metaphorically expressed by the saying of Heraclitus that *'one never steps in the same water of a flowing river'*, and also by his *"Panta rhei"–"Everything flows!"*). However, the recurrence of patterns of thoughts, ideas, mental 'images', as well as the need for *coherence of thought*, does seem to establish certain psychological 'states' (Ψ), psychological 'structures' (Φ), and indeed at least two 'modes' of consciousness: an active mode and a *'receptive', or 'meditative'* one. Whereas the 'active' mode would be involved in biological survival, motor, speech/language, abstract thinking, space or time perception and volitional acts (that might be localized in the left-side hemisphere for right-handed people), the 'receptive' mode would be involved in muscle-or general-relaxation, meditation, imagination, intuition, introspection, and so on (i.e., mental processes that do not require interaction with the outside world, and that might be localized in the right-side cerebral hemisphere in right-handed people). The related issue of the obvious presence of two functional hemispheres in the human brain has been the subject of substantial controversy concerning the possible dominance of the left-side brain over the right-side, as well as the possibility of a subject's survival with just one of his/her brain's hemisphere. All such related 'psi' categories and attributes are relevant to a mathematical representation of

consciousness as an ultra-complex, meta–process emerging through the integration of super-complex sub-processes or layers.

Fundamental ontology research into the nature of Life and Consciousness should be of very high priority to society in view of their importance for every human being. Clearly, a thorough understanding of how complex levels emerge, develop, and evolve to still higher complexity is a prerequisite for making any significant progress in understanding the human brain and the mind. Categorical Ontology and HDA are tools indeed equal to this hard task of intelligent and efficient learning about our own self, and also without straying into either a forest of irrelevant reductionist concepts or simply into Platonic meditation. Thus, such approaches and tools may not be enough for 'all' future, but it is one big, first step on the long road of still higher complexities.

4.6.1. *Intentionality, Mental Representations and Intuition.* We present here a concise summary of three essential mental processes, the first and second groups of processes being essential to the existence of human consciousness, and the third–that of intuition– seemingly key to human creativity beyond Boolean logic and step-by-step, 2-valued logic inferences. Although these cannot be at all separated from memory except in a formal sense, we are considering memory in a separate section as in the first instance the human mind retains and 'filters' representations of perceptions; obviously, the mind also memorizes ideas, concepts, elaborate mental constructs, etc. in addition to images, sounds, sensations, and so on. Furthermore, the physical basis, or supporting biophysical/neural processes of sensations and perceptions is much better understood than that of memory, or the other three key mental processes considered next.

4.6.2. *Intentionality.* Consciousness is always *intentional*, in the sense that it is always directed towards (or intends) ***objects*** (Pickering and Skinner, 1990). Amongst the earlier theories of consciousness that have endured are the *objective self-awareness* theory and Mead's (1934) *psychology of self-consciousness.* According to the pronouncement of William James (1890, pp.272-273),

> *"the consciousness of objects must come first".*

The reality of everyday human experience 'appears already objectified' in consciousness, in the sense that it is 'constituted by an '*ordering of objects*' (*lattice*) which have already been designated 'as objects' before being reflected in one's consciousness. All individuals that are endowed with consciousness live within a web, or *dynamic network*, of human relationships that are expressed through language and symbols as *meaningful objects.* One notes in this context the great emphasis placed on *objects* by such theories of consciousness, and also the need for utilizing '*concrete categories that have objects with structure'* in order to lend precision to fundamental psychological concepts and utilize powerful categorical/ mathematical tools to improve our representations of consciousness. A new field of categorical psychology may seem to be initiated by investigating the categorical ontology of ultra-complex systems; this is a field that might possibly link neurosciences closer to psychology, as well as human ontogeny and phylogeny. On the other hand, it may also lead to the 'inner', or *'immanent', logics* of human consciousness in its variety of forms, modalities (such as 'altered states of consciousness'-ACS) and cultures.

Furthermore, consciousness classifies different objects to different 'spheres' of reality, and is capable also of moving through such different spheres of reality. The world as 'reflected' by consciousness consists of multiple 'realities'. As one's mind moves from one reality to another the transition is experienced as a kind of 'shock', caused by the shift in attentiveness brought about by the transition. Therefore, one can attempt to represent such different 'spheres of reality' in terms of concrete categories of objects with structure, and also represent the dynamics of consciousness in terms of families of categories/'spheres of reality' indexed by time, thus allowing 'transitions between spheres of reality' to be represented by functors of such categories and their natural transformations for 'transitions between lower-order transitions'. Thus, in this context also one finds the need for categorical colimits representing coherent thoughts which assemble different spheres of reality (*objects reflected in consciousness*). There is also a common, or *universal, intentional character of consciousness.* Related to this, is *the apprehension of human phenomena as if they were '**things**'*, which psychologists call *'reification'.* Reification can also be described as the extreme step in the process of objectivation at which the objectivated world loses its comprehensibility as an enterprise originated and established by human beings. Complex theoretical systems can be considered as reifications, but "*reification also exists in the consciousness of the man in the street*" (Pickering and Skinner, 1990). Both psychological and ethnological data seem to indicate that the original apprehension of the social world (including society) is *highly reified* both ontogenetically and philogenetically.

Kant considered that the internal structure of reasoning, or the 'pure reason', was essential to human nature for knowledge of the world but the inexactness of empirical science amounted to limitations on the overall comprehension. At the same time, in his 'critique of the pure reason' Kant warned that transcedental ideas can be neither proven nor disproven as they cannot be phenomenally checked or validated. Brentano considered intentional states as defined via the mental representation of objects regulated by mental axioms of reason. As it is experienced, Freeman (1997,1999) regards intentionality as the dynamical representation of animal and human behaviour with the aim of achieving a

particular state circumstance in a sense both in unity and entirety. This may be more loosely coined as 'aboutness', 'goal seeking' and or 'wound healing'.

4.6.3. *Mental Representations- The Hypothesis of A $<$ System $>$ of Internal Representations in Psychology and Cognitive Sciences.* Mental representations are often considered in psychology and cognitive sciences (including neocognitivism, cf. Dennett, 1981) as fundamental; the concept has been therefore intensely debated by philosophers of psychology, as well as psychologists, and/or cognitive scientists. The following discussion of such concepts does not imply our endorsement of any of such possible philosophical interpretations even though it is hard to see how their consideration and the mental roles they play could be either completely or justifiably avoided. The important question of how *language-like* are mental representations is one that is often debated by philosophers of the mind.

According to Harman, "thought may be regarded as consisting in large part of *operations on 'sentences under analysis'.* (as cited in Hills, 1981). However, Harman, and also Fodor (1981), claim that only some mental representations are highly language-like, and that not all of them are such. Brentano's position regarding *intentionality* of mental representations was clearly stated as making the distinction between the physical and mental realms. Other philosophers are less supportive of this view; a cogent presentation of various positions adopted by philosophers of the mind vis a vis mental representations was provided by Field (Ch. 5 in Block, 1981). As pointed out by Field, postulating the *irreducibility* of mental properties (e.g., to physical or neurophysiological ones) raises two main problems: the problem of *experiential* properties and the problem of *intentionality* raised by Brentano. Most mental properties, if not all, seem to be *relational* in nature; some for example may relate a person, or people, to certain items called "propositions" that are usually assumed not to be linguistic. Field claims however that in order to develop a psychological theory of beliefs and desires one could avoid propositions altogether and utilize "something more accessible" that he calls *sentences.* Thus, mental representations would be expressed as relations between people and 'sentences' instead of propositions. Unlike propositions then, sentences do have linguistic character, such as both syntax and semantics, or else they are sentence-analogs with significant grammatical structure, perhaps following Tarski's compositional theory. On the other hand, Harman is quite critical of those compositional semantics that regard a *knowledge* of truth-conditions as what is essential in semantics (... '*'Davidson's theory would be circular*"). Furthermore, Gilbert Harman wrote: "no reason has been given for a compositional theory of meaning for whatever system of representation we think in, be it Mentalese or English", (p.286 in Gunderson, ed., 1975). Then, *"organisms which are sufficiently complicated for the notions of belief and desire to be clearly applicable have* ***systems of internal representations*** *(SIR) in which sentence-analogs have significant grammatical structure*", writes Field. On this hypothesis of SIR, a belief involves a ***relation between organisms and sentence-analogs in a SIR*** for organisms of 'sufficient complexity'. From a functionalism standpoint which abstracts out the physical structure of particular organisms, the problem arises how psychological properties are realized by such organisms, as well as the questions of how to define a *realization* of a psychological property, and how to define "what a psychological property itself is". Therefore, *"if you do not construe belief relationally, you need a physical realization of the belief relation"* (p. 91 of Field, 1981).

4.6.4. **Propositional Attitudes**. Following Fodor (1968) *propositional attitudes* are assumed to ascribe or represent *relations between organisms and internal representations* (p. 45). Furthermore, they seem to be often identified with the inner speech and/or thought. According to Fodor(1981), cognitive psychology is a revival of the representational 'theory' of the mind: "*the mind is conceived as an organ whose function is the manipulation of representations, and these in turn, provide the domain of mental processes and the (immediate) objects of mental states.*"

If mental representations, on the other hand, were to require the existence of an 'observer' or 'exempt internal agent' that can interpret what is being represented, one would face an infinite regress. Therefore, the claim was made that the human mind's representations related to the thinking process and/or human solving/cognition processes are in fact $<$ *representations* $>$ *of representations*, or even some kind of 'self-representation'. In this respect also, the human mind is *unique* by comparison with that of any lower animal, if the latter can be at all considered as a 'mind' because it clearly has only limiting boundaries and no conceivable horizon. Note the critique of the propositional attitude concept by Field in the previous subsection, and the latter's hypothesis that *sentence–analogs* in a SIR can replace propositional attitudes in psychology. The difference between the two views seems to lie in the specific nature of propositional attitudes (that may be somewhat intangible) and sentence-analogs in an SIR that may be 'tangible' in the sense of having significant grammatical structure (syntax, semantics, etc.), e.g., being more language-like. Furthermore, as attitudes are intentionality related the propositional *attitudes* may be more complex and richer than Field's sentence–analogs. One also notes that Rudolf Carnap (1947) suggested that propositional attitudes might be construed as *relations between people and sentences* they are disposed to utter. The reader may also note that in these two subsections, as well as in the next one, the emphasis is on the role of *relations* and properties–instead of objects–in the philosophy of psychology, and thus a categorical, logico-mathematical approach to SIR seems to be

here fully warranted, perhaps including a Tarskian compositional semantics, but with Harman's critical *proviso* and warnings cited above!

Either representational 'theory', or hypothesis, leaves open the questions:

1. What relates internal representations to the outside world?, and
2. How is SIR semantically interpreted? or How does one give meaning to the system of internal representations?

Perhaps Field's proposal could be implemented along the Tarskian compositional semantics in a many-valued setting, such as the Łukasiewicz generalized topos (LGT), that was first introduced in Baianu (2004, 2005) and which can provide an adequate conceptual framework for such semantic interpretations *with nuances specified by many truth values* instead of a single one!

4.6.5. *Intuition.* There is much that can be said about intuition in a logical or mathematical sense; this precise meaning of intuition is further addressed in the paper by Brown, Glazebrook and Baianu (2007) where the necessary, logical and mathematical concepts are also available in a rigorous form. In this section, we shall however consider the broader meaning of intuition, as it seems to play a major role in developing new concepts, theories, or even paradigm shifts. One may speak of intuition correlating to some form of intentionality which momentarily may not be derivable to a semantic/linguistic meaning regardless of a causal framework but may involve some kind of 'pictorial analogy'. Perhaps this is relevant to the sign language of the deaf and 'dumb', which is three–dimensional and contains semantic elements. But intuition may also involve nuances of learning and wording towards boundaries within the overlaps of 'fuzzy nets' which, as we propose, are based on the principles of non-commutative (multi-valued) n- Łukasiewicz logics (cf. Baianu et al., 2006; Georgescu, 1971; 2006). Ultimately, if an intuition is 'correct' or 'wrong' in the 'collective eyes of society', is determined through an *objectivation* process which pervades all human culture: it is either accepted or rejected by an intellectual majority in a specific human society. As this process is rarely based only on logic, and may also involve experiential considerations, objectivation does not have the 'permanent' character that this word may imply. Paradigm shifts in science are, in this sense, major re-considerations of objectivation of scientific concepts and theories. A remarkable paradigm shifts and re-objectivations seems to be now occurring in the ontology of higher complexity systems and processes, currently labelled as 'Complexity Theory' or 'Complex Systems Biology' (when the latter is restricted to living organisms).

An '*intuitive space*' or *intuition* **layer** of complexity (cf. Poli, 2006c; Baianu and Poli, 2008) might thus appear to exist apart from, or relatively independent of, how experiences can be rationalized. Since intuition is a property attributed to the human mind (or to the 'autobiographical self' in the sense of Damasio, 1994), it has therefore to be considered as conceptually different from 'instincts' or brain-initiated reflexes. In keeping with the above considerations, human 'intuition' may thus be regarded as a by–product of an ultra–complex 'system' of processes occurring in the unique human mind, an essential intrinsic attribute, of that 'system' of processes.

4.6.6. *Psychological Time, Spatial Perceptions, Memory and Anticipation.* Subdivisions of space and spatiotemporal recognition cannot satisfactorily answer the questions pertaining to the brains capability to register qualia–like senses arising from representations alone (such as a sense of depth, ambiguity, incongruity, etc.) Graphic art in its many forms such as cubism, surrealism, etc. which toy around with spatial concepts, affords a range of mysterious visual phenomena often escaping a precise neuro–cognitive explanation. For instance, we can be aware of how an extra dimension (three) can be perceived and analyzed from a lower dimensional (respectively, two) dimensional representation by techniques of perceptual projection and stereoscopic vision, and likewise in the observation of holographic images. Thus any further analysis or subdivision of the perceived space would solely be a task for the 'minds–eye' (see Velmans, 2000 Chapter 6 for a related discussion). Through such kaleidoscopes of cognition, the induced mental states, having no specified location, may escape a unique descriptive (spatiotemporal) category. Some exception may be granted to the creation of holographic images as explained in terms of radiation and interference patterns; but still the perceived three dimensional image is *illusory* since it depends on an observer and a light source; the former then peers into an 'artificial' space which otherwise would not have existed. However, the concept of holography heralds in one other example of the ontological significance between spacetime and spectra in terms of a fundamental duality. The major mathematical concept for this analysis involves the methods of *the Fourier transform* that decompose spatiotemporal patterns into a configuration of representations of many different, single frequency oscillations by which means the pattern can be re–constructed *via* either summation or integration. Note, however, that visualizing a 4-dimensional space from a picture or painting, computer-generated drawing, etc., is not readily achieved possibly because the human mind has no direct perception of *spacetime*, having achieved separate perceptions of 3D-space and time; it has been even suggested that the human brain's left-hemisphere perceives time as related to actions, for example, whereas the right-hemisphere is involved in spatial perception, as supported by several split-brain and ACS tests. This may also imply that in all other species–which unlike man– have symmetric brain hemispheres temporal perception–if it does exist at all– is not readily separated from space perception, at least not in terms of localization in one or the other brain hemisphere.

The mathematical basis relating to the topographical ideas of Pribram's models lies in part within the theory of harmonic analysis and (Lie) transformation groups. Relevant then are the concepts of (Lie) groupoids and their convolution algebras/algebroids (cf Landsman, 1998) together with species of 'localized' groupoids. Variable groupoids (with respect to time) seem then to be relevant, and thus more generally is the concept of a fibration of groupoids (see e.g. Higgins and Mackenzie, 1990) as a structural descriptive mechanism. Such observations, in principle representative of the ontological theory of levels, can be reasonably seen as contributing to a synthetic methodology for which psychological categories may be posited as complementary to physical, spatiotemporal categories (cf Poli 2008). Such theories as those of Pribram do not fully address the question of universal versus personal mind: how, for instance, does mind evolve out of spatiotemporal awareness of which the latter may by continuously fed back into the former by cognition alone? The answer –not provided by Pribram, but by previous work carried out by Mead (cca. 1850)–seems to be negative because human consciousness appears to have evolved through social, consensual communications that established symbolic language, self-talk and thinking leading to consciousness, as modelled above by the Rosetta biogroupoid of human/hominin social interactions. A possible, partial mechanism may have involved the stimulation of forming an increased number of specialized 'mirror neurons' that would have facilitated human consciousness and symbolism through the evoked potentials of mirror neuron networks; yet another is the *synaesthesia*, presumably occurring in the Wernicke area (W) of the left-brain, coupled to the 'mimetic mirror neurons' thus facilitating the establishment of permanent language centers (Broca) linked to the W-area, and then strongly re-enforced and developed through repeated consensual social human interactions. In the beginning, such interactions may have involved orderly rituals and ritual, 'primitive' dances whose repetitive motions and sensory perception acts may have enforced collectively an orderly 'state' in the primitive *Homo*'s minds. Such periodic and prolonged rituals in primitive societies–as suggested by Mumford (1979)– may have served the role of ordering the mind, *prior to*, and also facilitating, the emergence of human speech! Thus a collective system of internal representations and reification in the human mind may have had its very origin in the primitive rituals and ritualistic dancing prior to the development of truly human speech. The periodic, repetitive action of ritual dancing, charged with emotional content and intentionality, may have served as a very effective *training* means in such primitive tribal societies, much the same way as human champions train today by rhythmic repetition in various sports. Clearly, *both a positive feedback*, and a *feedforward (anticipatory)* mechanism were required and involved in the full development of human consciousness, and may still be involved even today in the human child's mind development and its later growth to full adult consciousness. Interestingly, even today, in certain tribes the grandfather trains the one-year old child to 'dance' thus speeding up the child's learning of speech. One can consider such observations as contributing substantially towards a resolution of the *'hard problem'* of consciousness: how can one fully comprehend the emergence of *non–spatial* forms arising from one that is *spatial* (such as the brain) within the subjective manifold of human sensibility? The functional brain matter is insentient and does not by itself explain causal, spatiotemporal events as agents of consciousness. However, there have been attempts as for example those made by Austin (1998) to 'link' the brain's neurobiology with the mind in order to explain the qualities of conscious experience, in this case within a Buddhist-philosophical (strictly *non-dual* or *monistic*) context of awareness; the latter is inconsistent with the Western, *dual* approach extensively discussed in this essay, in the sense of the mind vs. the brain, organism vs. life, living systems *vs* inanimate ones, super-complex *vs* simple systems, environment *vs* system, boundary *vs* horizon, and so on, considering them all as pairs of *distinct* (and *dual/apposed*, but not opposed) ontological items. Surprisingly, reductionism shares with Buddhism a *monistic* view of the world–but coming from the other, physical extreme– and unlike Buddhism, it reduces all science to simple dynamic systems and all cognition to mechanisms.

The questions of mind–brain 'interface' remain largely unanswered as there have been very few determined attempts at even posing correctly such questions, and even fewer at seriously investigating how the mind correlates with observable brain processes (for example through MRI, SQUID magnetometry, NIR/laser fluoresacence, PET scanning, etc. measurements on conscious *vs* unconscious human brains combined with detailed psychological studies). Whereas Kantian intuitionism seems to reduce matters to an interplay of intellect and imagination as far as differing qualities of 'space' are concerned, the dictum of physics claims without failure *'non–existence if it can't be measured'*. There are several philosophers who have made the claim of metaphysical limits upon intellectually conceived representations, to the extent that definitive explanations might remain beyond the grasp of human comprehension (e.g. Kant, 1778; McGinn, 1995). Others (cf. Bennett and Hacker, 2003) in part echoing Gilbert Ryle's pronouncement of "categorical problems" (Ryle, 1949)–in the philosophical sense (i.e., categorial)– argue that brain science alone cannot explain consciousness owing to a plague of intrinsic (metaphysical–categorial) errors such as when a certain neuropsychological entity is conceived as a 'linear' superposition of it constituent parts (cf 'the mereological fallacy'); in this regard, Bennett and Hacker (2003) spare no reductionist 'theories of neuroscience'.

Even though the human brain consists in a very large (approximately 100,000,000,000), yet finite, number of neurons– and also a much higher number of neuronal connections greater than 10^{29}– the power of thought enables conscious humans to construct symbols of things, or items, *apart from the things themselves*, thus allowing for our

extension of representations to higher dimensions, to infinity, enlightenment, and so on, paradoxically extending the abilities of human consciousness very far beyond the apparent, finite limitations, or boundaries, of our super-complex, unique human brain. One notes here also that the psychological concept of dynamic 'net without boundary' occurring and moving in the 'conscious plane', but often with a specific focus (McCrone, 1991), leads to a 'completely open', variable topology of the human mind. Thus, one may not be able to consider the human mind as a 'system' because it seems to possess no boundary– but as an *'open multiverse of many layers, or super-patterns of processes of processes,... with a horizon'.* The mind has thus freed itself of the real constraints of spacetime by separating, and also 'evading', through virtual constructs the concepts of time and space that are being divided in order to be conquered by the human free will. Among such powerful, 'virtual' constructs of the human mind(s) are: symbolic representations, the infinity concept, continuity, evolution, multi-dimensional spaces, universal objects, mathematical categories and abstract structures of relations among relations, to still higher dimensions, many-valued logics, local-to-global procedures, colimits/limits, Fourier transforms, and so on, it would appear without end. This view of the human mind seems consistent with the proposal made by Gregory Bateson, who put forward an interesting scheme of "*logical levels of meaning*", and went on to emphasize that the human 'mind is *not confined* to the body but ramifies out *informationally* into the symbolic universe around it.', i.e., the human mind alone has a horizon, not a strict, or fixed, boundary. Bateson also argued that the 'ecology of mind' is an *ecology of pattern*, *information, and ideas* embodied in things that are material forms. Thus, a science which would limit itself to counting and weighing such embodiments would only arrive at a very distorted understanding of the mind. Gregory Bateson characterized what he meant by a *mind* (or *mental 'system'*) in his "*Pathologies of Epistemology.*" (p.482), where a mental 'system' was defined as one with a capacity to process and respond to information in a *self–corrective* or *autopoietic* manner, just as it is the characteristic of living systems from cells to forests, and from primitive society to human civilizations. Then, he also developed such a characterization into a list of *defining criteria* for the human mind; in his view, the mind is composed of multiple material parts whose arrangements allow for *both process and pattern*. Upon this view, the human mind is **not separable** from its material base and the traditional Cartesian dualism separating the mind from the body, or the mind from matter, is considered erroneous; a 'mind'–in this extended Batesonian (but not Leibnitz-like) sense– can thus also include non–living components as well as multiple organisms; it may function for either brief or extended periods, and *is not necessarily defined by a boundary*, such as an enveloping skin or the skull. For Bateson, however, consciousness– if present at all– is always *only partial*. This emphasis on mental 'systems' as "including more than single organisms" leads Gregory Bateson to insisting that the *unit* of survival is always *the organism and its environment*. Furthermore, Bateson elaborates the notion that in the world of mental processes, the *difference* is the analog of ***cause*** (the " *difference that makes a difference*"), and then argues that embedded and interacting systems have a capacity to select a pattern, or patterns, from apparently random elements, as it happens in both evolution and learning; he calls the latter "two great stochastic processes." Interestingly, he was also able to explore the way in which such an analogy underlies all the *"patterns which connect"*. Then, Bateson develops a typology of habitual errors in the ways of thinking, some that are only minor, and some that are potentially lethal. Although the human mind is able to conceive higher dimensions and infinity, it may also lead through the wrong political decisions to the total destruction of life and consciousness on earth–as in a nuclear 'accident', or through intentional conflagration and environmental destruction. This moral and societal 'duality'–as long as it persists– may make to us, all, the difference between the continued existence of human society and its irreversible disappearance on earth. As an informational related cause, Bateson for example traced the origin of *destructive* human actions to *inappropriate descriptions*, and also argued that '*'what we believe ourselves to be should be compatible with what we believe of the world around us,*" (Bateson, G and M.C. Bateson, 1987); yet, knowledge and belief do involve deep chasms of ignorance or unknowing. Bateson was thus convinced that human society should have a "respect for the systemic integrity of nature, in which all plants, animals and humans alike, *are part of each other's environment*", albeit as *unequal* partners.

4.7. **Emergence of Organization in Human Society: Social Interactions and Memes.** We shall consider first an emergent human pre-historic society and then proceed to examine the roles played by social interactions and memes generated by society. Finally, we shall consider the potential dangers of arbitrary political decision–making that could lead to accidental but permanent extinction of both human civilization and all life on earth.

4.7.1. *A Rosetta Biogroupoid of Social, Mutual Interactions: The Emergence of Self and Memes through Social Interaction.* One may consider first a human pre-historic society consisting of several individuals engaged in hunting and afterwards sharing their food. The ability to share food seems to be unique to humans, perhaps because of the pre-requisite *consensual* interactions, which in their turn will require similar mental abilities, as well as an understanding of the need for such sharing in order to increase the survival chances of each individual.

A Rosetta Biogroupoid of Social Interactions.

It seems that the awareness of the self of the other individuals developed at first, and then, through an extension of the concept of others' self to oneself, *self awareness* emerges in a final step. Such pre–historic societal interactions that are based on consensus, and are thus mutual, lead to a natural representation of the formation of 'self' in terms of a *'Rosetta biogroupoid'* structure as depicted below, but possibly with as many as twenty five branches from the center, reference individual:

$$\begin{tikzcd} & \text{Neighbour's Self} \arrow[d, leftrightarrow] & \\ \text{Neighbour's Self} \arrow[r, leftrightarrow] & \text{Oneself} \arrow[r, leftrightarrow] \arrow[d, leftrightarrow] & \text{Neighbour's Self} \\ & \text{Neighbour's Self} & \end{tikzcd} \tag{4.4}$$

Diagram 4.9.2: *A Rosetta biogroupoid* of consensual, societal interactions leading to self-awareness, one's self and full consciousness; there could be between 4 to 24, or more individuals in a pre-historic society of humans; here only four are represented as branches.

One may consider modern society as a second order meta-level of the human organism, with the ultra—complex system of the human mind, as its first order meta–level. The overall effect of the emergence of the unique, *ultra-complex human mind meta–level* and the co-evolution of human society has been the complete and uncontested *dominance* by man of all the other species on earth. Is it possible that the emergence of the highly complex society of modern man is also resulting in the eventual, complete domination of man as an individual by 'his' highly complex society ? The historical events of the last two centuries would seem to be consistent with this possibility, without however providing certainty of such an undesirable result. However, ontological theory of levels considerations seem to exclude such a possibility as the resulting (hypothetical, 'first-order meta-level' society would be non-generic and thus unstable. Furthermore, as we have seen that society has strongly influenced human consciousness, indeed making possible its very emergence, what major effect(s) may the modern, highly complex society have on human consciousness? Or, is it that the biological (evolutionary) limitations of the human brain are preventing, or partially 'filtering out' the complexification pressed onto man by the highly–complex modern societies? There are already existing arguments that human consciousness has already changed since ancient Greece, but has it substantially changed since the beginnings of the industrial revolution? There are indications of human consciousness perhaps 'resisting'– in spite of societal reification–changes imposed from the outside, perhaps as a result of *self-preservation of the self.* Hopefully, an improved complexity/super- and ultra–complexity levels theory, as well as a better understanding of spacetime ontology in both human biology and society, will provide answers to such difficult and important questions.

Social Interactions and Memes.

Our discussion concerning the ontology of biological and genetic networks may be seen to have a counterpart in how scientific technologies, socio–political systems and cultural trademarks comprise the methodology of the planet's evolutionary development (or possibly its eventual demise!). Dawkins (1982) coined the term 'meme' as a unit of cultural information having a societal effect in an analogous way to how the human organism is genetically coded. The idea is that memes have 'hereditary' characteristics similar to how the human form, behaviour, instincts, etc. can be genetically inherited. Csikzentmihalyi (1990) suggests a definition of a meme as "any permanent pattern of matter or information produced by an act of human intentionality". A meme then is a concept auxiliary to that of the ontology of a 'level': to an extent, the latter is the result of generations of a 'memetic evolution' via the context of their ancestry. Memes occur as the result of a neuro–cognitive reaction to stimuli and its subsequent assimilation in an effective communicable form. Any type of scientific invention, however primitive, satisfies this criteria. Once a meme is created there is a subsequent inter–reaction with its inventor, with those who strive to develop and use it, and so forth (e.g. from the first four–stroke combustion engine to the present day global automobile industry). Csikzentmihalyi (1990) suggests that mankind is not as threatened by natural biological evolution as by the overall potential content of memes. This is actually straightforward to see as global warming serves as a striking example. Clearly, memetic characteristics are however quite distinct from their genetic counterparts. Cultures evolve through levels and species compete. Memetic competition can be found in the conflicting ideologies of opposing political camps who defend their policies in terms of economics, societal needs, employment, health care, etc. Whether we consider the meme in terms of weapons, aeronautics, whatever, its destiny reaches to as far as mankind can exploit it, and those who are likely to benefit are the founding fathers of new industrial cultures, inventors and explorers alike, the reformers of political and educational systems, and so on. Unfortunately, memes can create their own (memetic) 'disorders', such as addiction, obesity and pollution. Thus, to an extent, human memetic systems are

patently complex, and they may represent ontologically different sublevels of the society's meta–level possessing their own respective characteristic orders of causality.

Related to memetic and autopoietic systems are those of *social prosthetic systems* (Kosslyn, 2007) in which the limitations of the individual cognitive capacity can be extended via participation within varieties of socio–environmental networks. Loosely speaking, the mind 'uses' the world and 'enduring relationships" as extensions of itself. As for many of the highly complex systems considered in this essay, the underlying structures can be represented in terms of equivalence classes, thus leading to configurations of either Rosetta groupoids of social interactions, and/or to the more complex groupoid atlas structure.

4.8. **The Human Use of Human Beings. Political Decision Making.** In his widely-read books on Cybernetics and Society, Norbert Wiener (1950, 1989) attempted to reconcile mechanistic views and machine control concepts with the dynamics of modern society. He also advocated the representation of living organisms in terms of *variable* machines or variable automata (formally introduced in Baianu, 1971b). As discussed in previous sections, the variable topology is a far richer and extremely flexible structure, or system of structures, by comparison with the rigid, semigroup structure of any machine's state space. Thus, a variable topology dynamics provides a greatly improved metaphor for the dynamic 'state spaces' of living organisms which have emerged as super-complex systems precisely because of their variable topology. Many other society 'evolution' issues, and well-founded concerns about the human misuse of human beings, raised by Wiener are much amplified and further compounded today by major environmental issues. It remains to be seen if complexity theories will be able to fare better than Cybernetics in addressing *'the human use of human beings'* as Wiener has so aptly labelled the key problem of human societies, past and present. Wiener's serious concerns towards rigid and unjustified control of academic freedom through arbitrary political decisions by 'politically powerful' administration bureaucrats, as well as the repeated, gross misuses of scientific discoveries by politicians/dictators, etc., are even more justified today than half a century ago when he first expressed them; this is because the consequences of such severe controls of creative human minds by uncreative ones are always very grave indeed, in the sense of being extremely destructive. Thus, it is not the A– or H–/neutron bombs 'in themselves' that are extremely dangerous, but the political intent/potential, or actual decision to make and use them against human beings which is the culprit. Such considerations thus lead one into the subjects of ethics and morality, two very important philosophical/ontological fields that remain well beyond the horizon of our essay.

5. Conclusions and Discussion

Current developments in the SpaceTime Ontology of Complex, Super-Complex and Ultra-Complex Systems were here presented covering a very wide range of highly complex systems and processes, such as the human brain and neural network systems that are supporting processes such as perception, consciousness and logical/abstract thought. Mathematical generalizations such as higher dimensional algebra are concluded to be logical requirements of the unification between complex system and consciousness theories that would be leading towards a deeper understanding of man's own spacetime ontology, which is claimed here to be both *unique* and *universal*.

New areas of Categorical Ontology are likely to develop as a result of the recent paradigm shift towards non-Abelian theories. Such new areas would be related to recent developments in: non-Abelian Algebraic Topology, non-Abelian gauge theories of Quantum Gravity, non-Abelian Quantum Algebraic Topology and Noncommutative Geometry, that were briefly outlined in this essay in relation to spacetime ontology.

Contrary to Spencer's statements (1898), matter, space and time do have known, definite attributes, and so does indeed Spacetime–a concept introduced later by Einstein and Minkowsky through a logical/mathematical, rigorous *synthesis* of experimental results with critical thinking and the elimination of the 'ether'. One notes however that the current physical concept of *vacuum* is far from being just empty space. Furthermore, according to Einstein and Weyl (and seemingly also to Riemann), spacetime is curved and its curvature is changed by the presence of matter–*both* substance and energy (cf. Einstein). Contrary to Kantian-like thinking, there is no *a priori* idea of spacetime, although a Kantian might still argue that spacetime is no more than a transcedental idea whose phenomenal (objective) existence is ambiguous and whose dimensions and fine structure are yet to be properly conceived. There is currently a consensus that spacetime is *relative* as stated by Poincaré and Einstein, not the Newtonian absolute, even though it has an *objective existence* (consistent with Spencer's (1898) contention that the Absolute has no objective existence). Also consistent with Spencer' s philosophy, spacetime is currently thought to be finite; thus, Spencer also thought that the "Infinite is inconceivable!" . Standard quantum theories, including the widely-accepted 'Standard Model' of physics, lack the definition of either a time or a spacetime operator, but does have a space operator. Prigogine' s introduction of a microscopic time super–operator, concisely presented in Section 2, is only a partial solution to this problem in quantum theory that allows the consideration of *irreversible* processes without which Life and Consciousness would be impossible, but that ultimately result also in their inevitable global disorganization ('ageing') and demise; for example, Prigogine's time super–operator can be properly defined only

for quantum systems with an *infinite* number of degrees of freedom. On the other hand, introducing a *spacetime super–operator* in quantum theory- *à* la Prigogine's microscopic time super–operator - generates its own new series of problems, and of course, there is no such operator/super–operator defined in either Einstein's GR/SR or Newtonian mechanics. As complex, super– and ultra–complex dynamics is defined in essence by *irreversible* processes evolving in spacetime, which are the result of a multitude of quantum interactions and processes, the understanding and rigorous treatment of highly–complex systems is also affected by the limitations of current quantum theories; some of these current quantum–theoretical limitations in attempted applications to living organisms have been already pointed out by Rosen (2000) and Baianu et al (2006, 2007a). In two related papers (Baianu, Brown and Glazebrook, 2007; Brown, Glazebrook and Baianu, 2007), we have also considered further spacetime ontology developments in the context of Astrophysics, and also introduced novel representations of the Universe in terms of quantum algebraic topology and quantum gravity approaches based upon the theory of categories, functors, natural transformations, quantum logics, non-Abelian Algebraic Topology and Higher Dimensional Algebra; these approaches were then integrated with the viewpoint of Quantum Logics as part of a Generalized 'Topos'–a new concept that ties in closely Q-logics with many-valued, LM-logics and category theory. The latter synthesis may have consequences as important as the joining of space and time in the fundamental concept of spacetime modified by matter and energy.

The claims made in this essay are summarized as follows:

• The *non-commutative*, fundamentally 'asymmetric' character of Categorical Spacetime Ontology *relations and structure*, both at the top and bottom levels of reality; the origins of a paradigm shift towards non-Abelian theories in science and the need for developing a *non-Abelian Categorical Ontology*, especially a complete, non-commutative theory of levels founded in LM– and Q– logics. The potential now exists for exact, symbolic calculation of the non-commutative invariants of spacetime through logical or mathematical, precise language tools (categories of LM–logic algebras, generalized LM–toposes, HHvKT, higher Dimensional Algebra, ETAS, and so on).

• The existence of *super-complex* systems in the form of organisms/biosystems which emerged and evolved through dynamic symmetry breaking from the molecular/quantum level, that are not however reducible to their molecular or atomic components, and/or any known physical dynamics; succinctly put: ***no emergence*** $\Longrightarrow$ ***no real complexity***;

• The co-evolution of the unique human mind(s) and society, with the emergence of an ultra–complex level of reality; the emergence of human consciousness through such co-evolution/societal interactions and highly efficient communication through elaborate speech and symbols. Following a detailed analysis, the claim is defended that the human mind is more like a *'multiverse with a horizon, or horizons'* rather than merely a *'super-complex system with a finite boundary'*.

• There is an urgent need for *a resolution of the moral duality* between creation/creativity and destruction posed to the human mind and the current society/civilization which is potentially capable of not only self-improvement and progress, but also of total Biosphere annihilation on land, in oceans, seas and atmosphere; the latter alternative would mean the *complete, rapid and irrevocable* reversal of four billion years of evolution–a total destruction rather than mere involution. Arguably, the human minds and society may soon reach a completely unique cross-road–a potentially non-generic/strange dynamic attractor–unparalleled since the emergence of the first (so humble) primordial(s) on earth.

Furthermore, claims were also defended concerning important consequences of non-commutative complex dynamics for human society and the Biosphere; potential non-Abelian tools and theories that are most likely to enable solutions to such ultra-complex problems were also pointed out in connection with the latter consequences. We have thus considered here a very wide range of important problems whose eventual solutions require an improved understanding of the ontology of both the space and time (spacetime) dimensions of 'objective' reality especially from both the relational complexity and universality/ categorical viewpoints. Rapid progress through fundamental, cognitive research of Life and Human Consciousness that employs highly efficient, non-commutative tools, and/or precise 'language' is of greatest importance to human society. Such progress necessarily leads to the development of a complete Categorical Ontology Theory of Levels and Emergent Complexity.

However, we have been unable to cover here in any significant detail the broader, and very interesting implications of *objectivation* processes for human societies, cultures and civilizations. Furthermore, there are several possible extensions of our approach to investigating globally the *biosphere*. **Biosphere** $\Longleftrightarrow$ **Environment interactions** remain however as a further object of study in need of developing a formal definition of the horizon concept, only briefly touched upon here.

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